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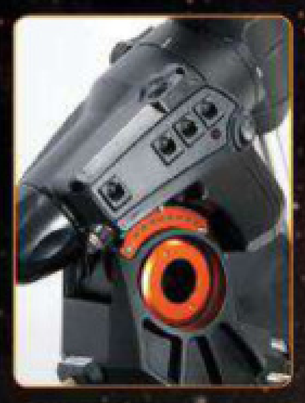
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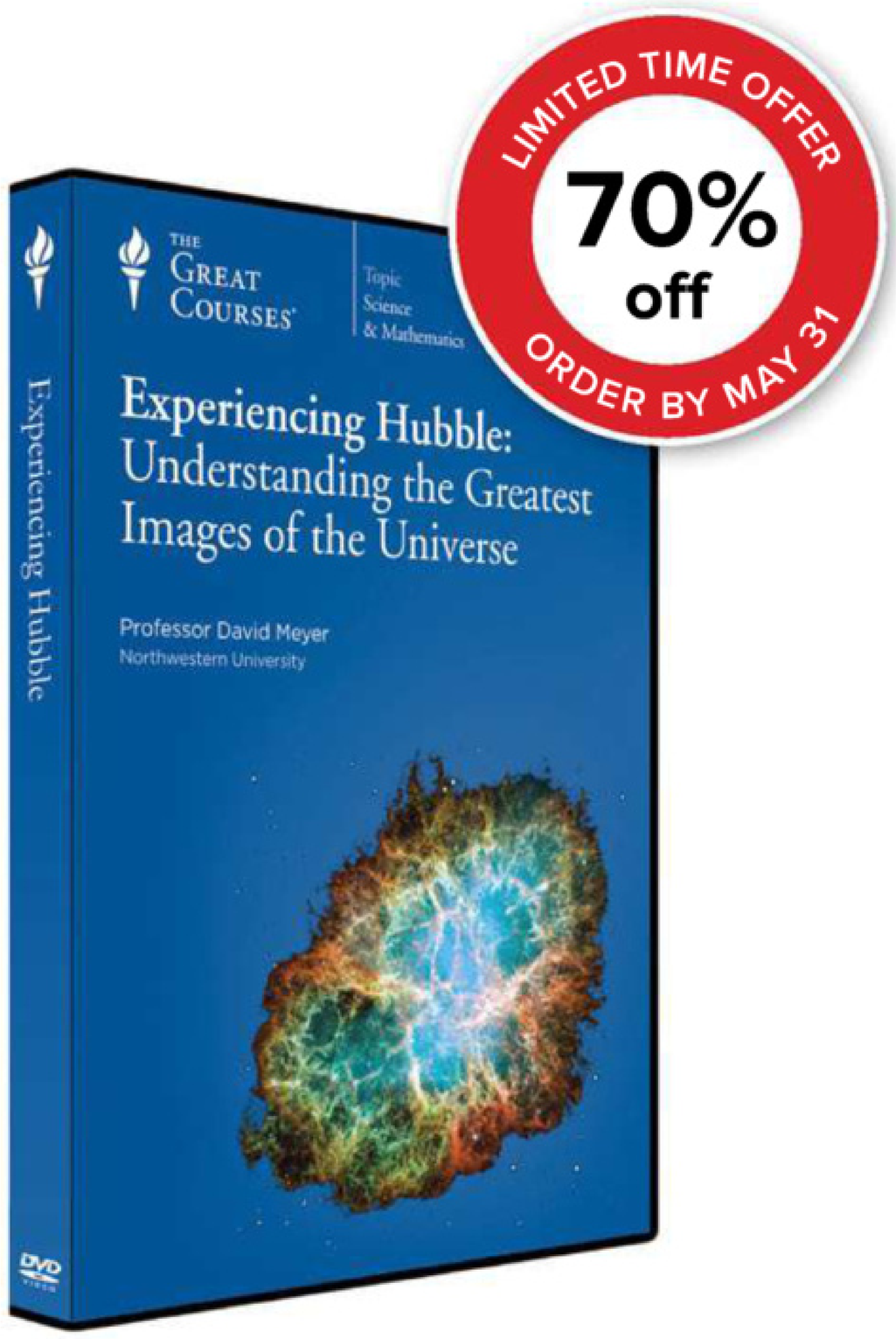
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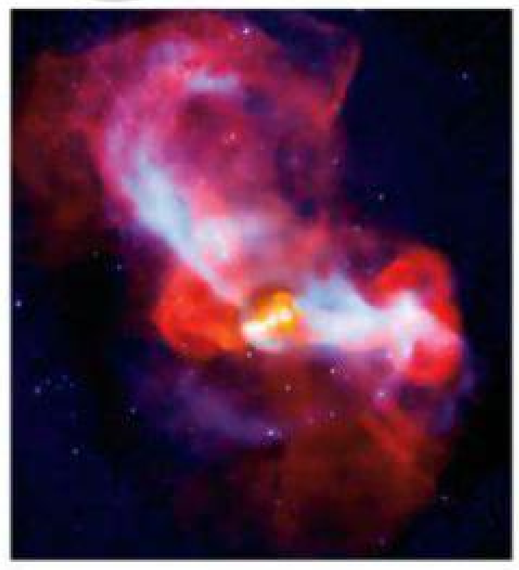
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ON THE COVER

X-ray and radio observations are helping astronomers figure out how the galaxy M87 heats its gas.

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FROM THE **EDITOR**

BY DAVID J. EICHER

The Northeast Astronomy Forum

Once again, *Astronomy* magazine will be a proud sponsor this year of the largest telescope show and amateur astronomy expo in the United States, the Northeast Astronomy Forum (NEAF). This year's NEAF will be held April 12–13 at Rockland Community College in Suffern, New York, about an hour's drive northwest of New York City. The event features exhibitors showing their telescopes, binoculars, cameras, and accessories and boasts more than 115 manufacturers and retailers. *Astronomy* magazine will have a display booth on hand, and I encourage you to stop by and say hello.

Each year, NEAF is organized and coordinated by members of the Rockland Astronomy Club, including Ed Siemenn and Al Nagler, the latter president of Tele Vue Optics. Several thousand people are expected to attend this year's event, which is open 8:30 A.M.–6 P.M. on Saturday the 12th and 10 A.M.–5 P.M. on Sunday the 13th.

In addition to more telescopes than you can possibly imagine, NEAF features talks by guest scientists and amateur astronomers. Presenters will include Matthew Greenhouse, project scientist for the Science Instrument Payload on the James Webb Space Telescope, who will update everyone on progress with the next big orbiting observatory, and Richard Fienberg, press officer of the American Astronomical Society, who will describe current collaborations between professional and amateur astronomers.



NEAF at Rockland Community College. DAVID J. EICHER

I will deliver a talk on comets, describing their physics, history, culture, and current science and also award the prizes for winning entries in our Comet ISON Photo Contest that *Astronomy* magazine held in conjunction with the National Science Foundation and *Discover* magazine.

Meteorologist and amateur astronomer Joe Rao will describe the link between Comet 209P/LINEAR and a possible new meteor shower. Solar enthusiast Stephen Ramsden of the Charlie Bates Solar Astronomy Project will describe how amateurs can observe the Sun. *Sky & Telescope* magazine Web Editor Monica Young will deliver a presentation on black holes.

And there will be many more talks! Find more information at http://tiny.cc/pgfubx/NEAF.

In addition to NEAF, a two-day imaging meeting, the Northeast Astro-Imaging Conference (NEAIC), precedes the weekend event. This is a group of tutorials for serious astroimagers, and it will take place Thursday, April 10, and Friday, April 11, at the Crowne Plaza Conference Center in Suffern. This event is also arranged by a group of New York amateur astronomers.

This year's NEAIC lineup includes a who's who of speakers: Ken Crawford, Ron DiLulio, Gordon Haynes, Jerry Hubble, Benjamin Mazin, Jim Moronski, Martin Pugh, and others. It will be an essential event for anyone who wants to capture their own images of the sky! Find more information at http://tiny.cc/pgfubx/NEAIC.

I'll look forward to seeing many of you at NEAIC and NEAF. It's one of the highlights of an amateur astronomer's year!

Yours truly,



David J. Eicher
Editor

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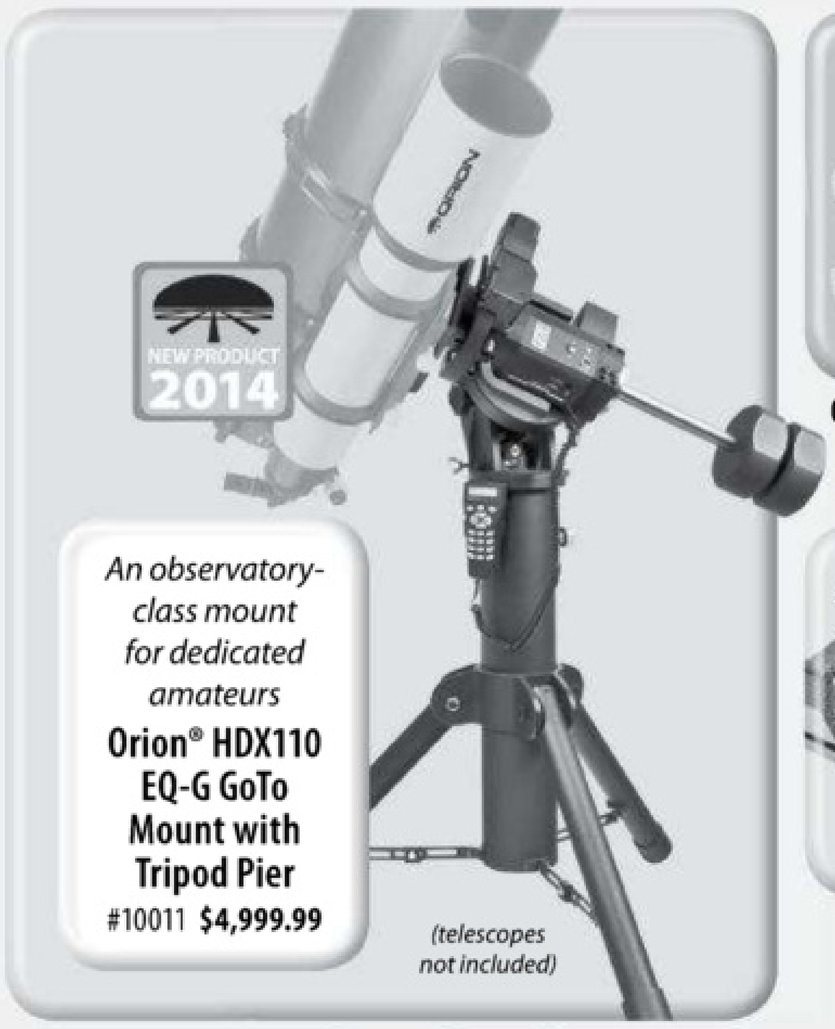
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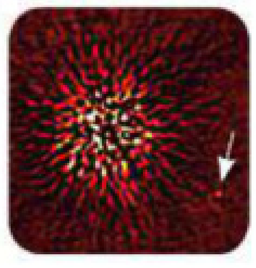
EVERYTHING YOU NEED TO KNOW ABOUT THE UNIVERSE THIS MONTH . . .

HOT BYTES >>

TRENDING TO THE TOP



GLOWING GAS
Astronomers found a piece of the cosmic web — a gas filament about 1.5 million light-years long — by studying an embedded luminous galaxy.



IMAGED DWARF
The brown dwarf associated with the star HD 19467 is at least 52 times Jupiter's mass and glows at 1050 kelvins (1430° Fahrenheit), say scientists.



COSMO-CHEM
New research suggests that astronomers can piece together the Milky Way's history by comparing stars' chemical compositions and movements.

SNAPSHOT

Portrait of a weird moon

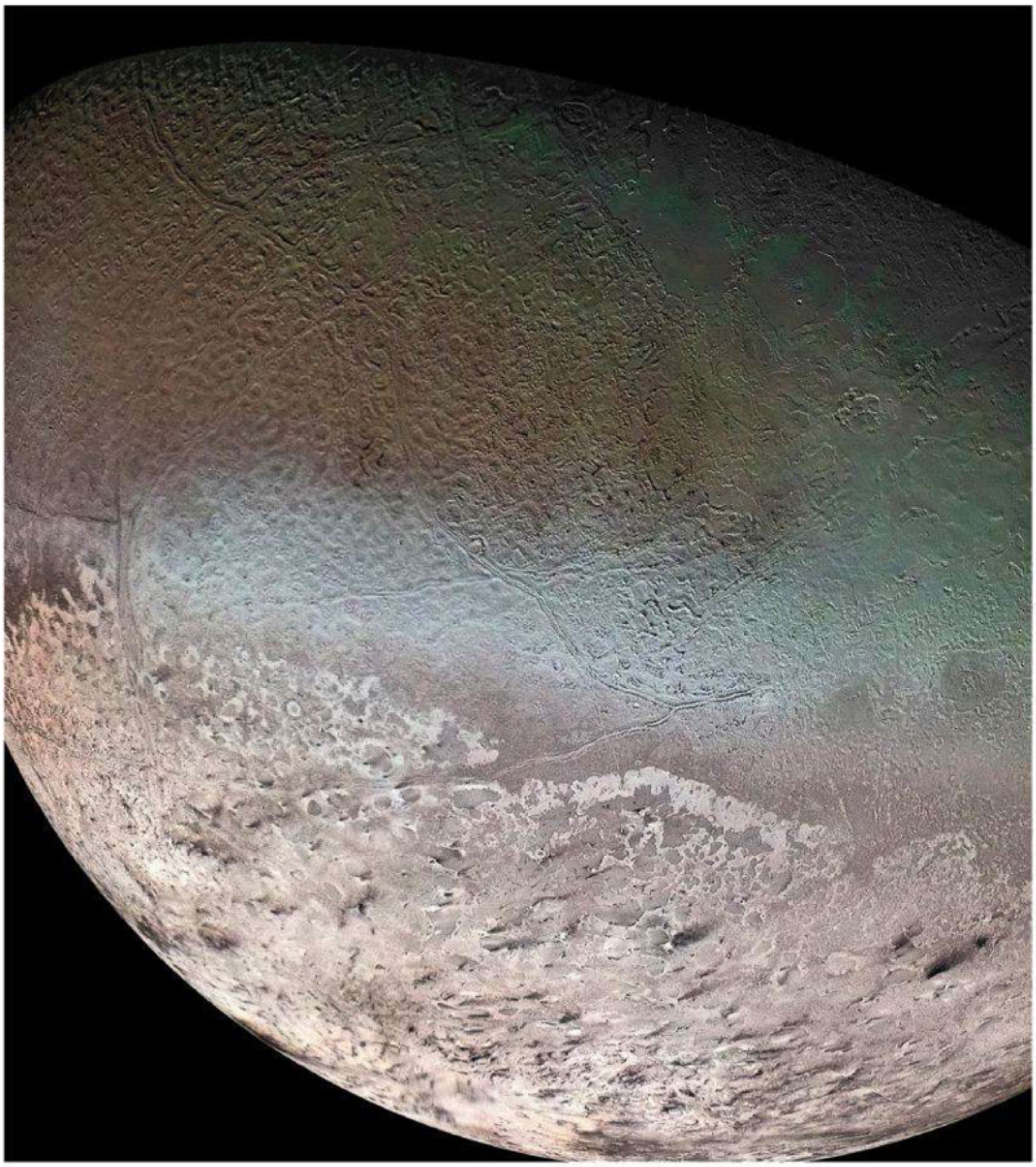
Neptune's Triton is unlike any other solar system body.

Often called a "cantaloupe" for its weirdly variegated surface, marked by twisting, crumpled ridges, Triton is a bizarre world. The most distant of the major moons in the solar system, Triton has characteristics of both classes of satellites — the big spherical ones and the tiny irregular ones. Triton is spherical and spans 1,682 miles (2,707 kilometers), making it one of the largest moons known.

The moon orbits Neptune in a retrograde motion — that is, it travels in a direction opposite that of the planet's rotation at all times. What makes Triton even stranger is its surface. It is young, contains geysers that vent nitrogen and dust, and has few craters. The twisting cantaloupe terrain seems to have formed from cold ammonia-rich material seeping upward.

Look for a story about Triton and other weird solar system moons next month.

— David J. Eicher



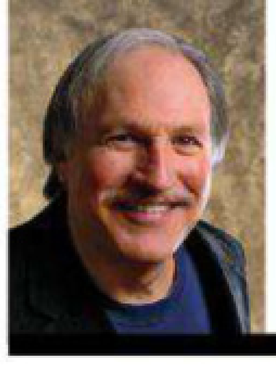
Neptune's moon Triton is one of the strangest worlds to classify for planetary scientists. NASA/JPL/USGS

S. CANTALUPO (GLOWING GAS); CREPP; ET AL. 2014, ApJ (IMAGED DWARF); SIMULATION: JAMES BULLOCK (COSMO-CHEM)

BREAK THROUGH

The Archer's baby boom

Although the spiral arms of the Milky Way harbor many impressive clouds of gas and dust, few rival the Lagoon Nebula (M8) in Sagittarius the Archer. During the past few million years, the Lagoon has spawned thousands of stars as dense pockets of gas collapsed under their own weight. The hottest of these suns excite the surrounding hydrogen atoms and cause them to glow with a characteristic reddish color. M8 spans approximately 100 light-years and lies roughly 5,000 light-years from Earth. Astronomers captured this image with the 2.6-meter VLT Survey Telescope on Cerro Paranal in northern Chile. ESO/VPHAS+ TEAM



STRANGE**UNIVERSE**

BY BOB BERMAN

Hunting for the glorious

Responses to certain celestial objects defy logic.

Some of life's greatest experiences need no narration. They are stand-alone glories. Rent a houseboat on the Southwest's Lake Powell, and lose yourself in a random side canyon. A tour guide with knowledge of geology could enhance the experience, but you'll be in heaven even if no one says a word.

Same with the sky. Even if your Aunt Betty doesn't know the difference between an asteroid and a hemorrhoid, she'll still "ooh and aah" at the gibbous Moon through your eyepiece. She doesn't have to know the big terraced crater is named Copernicus. It's gorgeous even in anonymity.

Saturn, its rings displayed better than they've appeared for the past nine years, is another winner these nights. You can boost someone's intellectual enjoyment by mentioning that those rings are so thin relative to their length that they're analogous to a sheet of paper the size of a city block. But even if you offer your visitor only a soundtrack of silence, they'll be swept away. Like the Taj Mahal, the apparition alone says it all.

But why do some celestial objects pack a punch while others don't? In some cases, it's a matter of visibility. A view of the Milky Way has been absent from city skies for nearly a century. Most people today have never seen it, or perhaps barely so. When vacationing urbanites venture into less populated regions where the Milky Way does manage to appear, it's still often subtle.

But take these people to truly dark skies, like the Sonoran Desert of the American Southwest, the Chilean Andes, or Egypt's White Desert. Get them there on a moonless night, preferably between August and October. Now the Milky Way dominates everything. Its mottled structure ambles insanely across the sky like modern art. Its rich detail is so bright that it actually casts shadows. Instantly, you grasp why some early cultures like the Maya regarded it as the night's focal point. All the discoveries scientists have made about our home galaxy become mere afterthoughts.

In a truly natural setting, the Milky Way dominates the night with an ineffable beauty and powerful presence that ranks it among life's best visual experiences. Yet it remains a mere concept in today's light-polluted universe — a textbook item.

A total solar eclipse provides another case of beauty trumping science. Relatively few have seen one, as such events occur just once every 360 years for any given place on Earth. Most people assume that they are merely another eclipse variety, in the same coolness pool as lunar eclipses or partial solar events, which unfold periodically and are interesting but certainly not life-altering. When an observer raves about her solar totality encounter, relating how animals go nuts and people weep and how it's the most sacred, soul-touching event of her life, the listener assumes exaggeration is at play. In our ubiquitous camera era, not everyone gets that some things in life *must* be experienced in person.

But why should the Moon covering the Sun make anyone weep? Why should the rings of Saturn evoke gasps? What is it about these celestial spectacles that so deeply touches the spirit? There's no logic to it.

This is not to belittle the intellectual side of space. Serious backyard astronomers enjoy the smudgy streaks of spring's myriad galaxies. When casual visitors see the same thing, however, their reaction is a scientific fascination but rarely a *visceral* response.

But the problem is not faintness. Brilliant Mars, now at its best of the year, similarly fails to evoke awe at the eyepiece. (Of course, I'm generalizing and also excluding serious astronomers, who basically love everything.)

Here the culprits are familiarity and heightened expectations. Everyone's seen sharp Hubble Space Telescope images of the Red Planet. Folks are aware of how Mars is "supposed" to look, so your blurry 15-arcsecond-wide wiggly disk cannot compete. By contrast, your guest likely has not heard of M13 — nor even seen a globular cluster — so an 8-inch instrument on a dark May night creates a reliable thrill when pointed toward Hercules. Oddly, a dense star concentration against a black background reliably awakens our sense of awe.

That's why plain binoculars are sometimes all you need, as with the Pleiades. Other times, the naked eye provides the ticket to glory. Aurorae and great comets always have been trustworthy portals to splendor. With telescopes, only a dozen targets elicit consistent gasps, and if you've been at this awhile, you know what they are.

The perception of beauty and the human reaction to celestial objects are rather mysterious topics that lie outside scientific analysis. But by learning where and how they work their magic, you can gain a powerful tool for making new friends for astronomy.

And on a personal greedy level, it's no small satisfaction to spoon-feed a bit of heaven to your favorite companions. You say, "Open wide!" and give them treats not for their minds, but for an inner place that's older and more enigmatic.

THE PERCEPTION OF BEAUTY AND THE HUMAN REACTION TO CELESTIAL OBJECTS ARE RATHER MYSTERIOUS TOPICS.

Contact me about my strange universe by visiting **http://skymanbob.com.**

FROM OUR INBOX

Warm, fuzzy names for comets

By now, Comet PANSTARRS (C/2011 L4) is well on its way back out to the distant, icy Oort Cloud. Comet ISON (C/2012 S1), meanwhile, is toast. Roasted. For all the anticipatory hoopla and predictive fanfare, neither of these comets was very bright. Maybe if we name the next comets after humans, they will become the crowd-pleasing great ones we look forward to.

— **Brian Ward,** Beverly Hills, California

We welcome your comments at Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; or email to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

BROWSE THE "STRANGE UNIVERSE" ARCHIVE AT **www.Astronomy.com/Berman.**

PASSING GRADE. The next big thing in space — NASA's James Webb Space Telescope — shot past its first milestone of the year January 24. Expert examiners determined its power, communications, and pointing control systems are, so far, good to go.



WATER VAPOR WISPS. This artist's impression of Ceres shows a new view of the dwarf planet: Evidence suggests it has a thin water vapor atmosphere.
ESA/ATG MEDIALAB

HERSCHEL FINDS WATER VAPOR AT CERES

Ceres, both a dwarf planet and the largest asteroid in the main belt between Mars and Jupiter, doesn't often reveal its mysteries to astronomers on Earth. That's why scientists currently have a spacecraft called Dawn en route to the object to study it up close. In advance of that rendezvous, though, researchers have been able to make a definitive detection of water vapor at Ceres, according to a paper published in the January 23 issue of *Nature*.

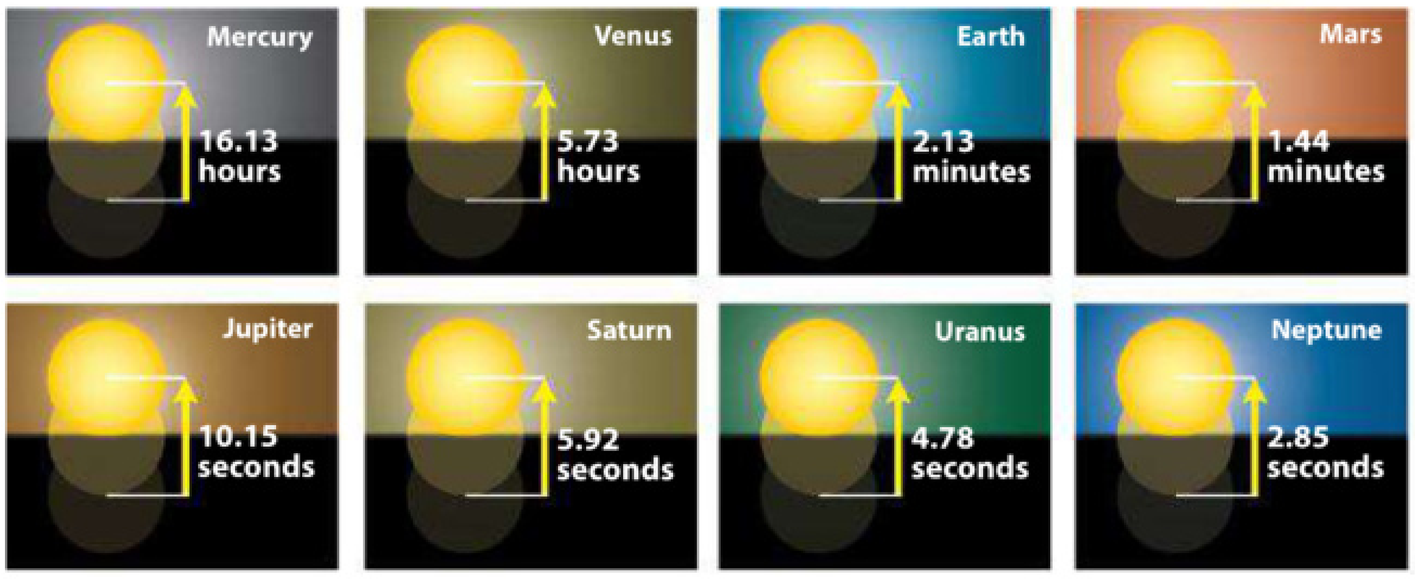
Using the advanced sensitivity of the European Space Agency's (ESA) Herschel Space Observatory, scientists identified wisps of water vapor during three of four observation periods. "This is the first time water vapor has been unequivocally detected on Ceres or any other object in the asteroid belt and provides proof that Ceres has an icy surface and an atmosphere," says lead author Michael Küpper of ESA. The team was even able to narrow down the source of the vapor to two mid-latitude regions on the dwarf planet's surface that appear darker than their surroundings.

Although they don't yet know the cause of the wisps, the researchers suggest two possibilities: comet-like sublimation of surface ice turning directly to gas or cryovolcanoes triggered by an internal heat source. But they won't have to wait long for answers, thanks to Dawn's arrival in early 2015. "We don't really have to guess; in a year we'll be there," says Christopher Russell, lead investigator for the mission at the University of California, Los Angeles. "Once we get there, we'll figure out where [the water] is getting out and how." — **Karri Ferron**

THE SUN ALSO RISES

Although no longer considered a major planet, distant Pluto would experience a sunrise lasting 20.67 seconds.

FAST FACT



DAWN BREAKS. How long does it take the Sun's disk to clear the horizon once its upper limb first comes into view? The answer varies wildly among the solar system's planets — from mere seconds to several hours. It's not surprising that Mercury experiences the longest sunrise; after all, it has the longest day (4,223 hours), and the Sun looms largest (1.4° across) in its sky. All four giant planets have short sunrises because they rotate quickly and lie far from the Sun. The values here are averages for an observer located on each planet's equator.

ASTRONOMY: RICHARD TALCOTT AND ROEN KELLY

BRIEFCASE

RACE TO OUTER SPACE

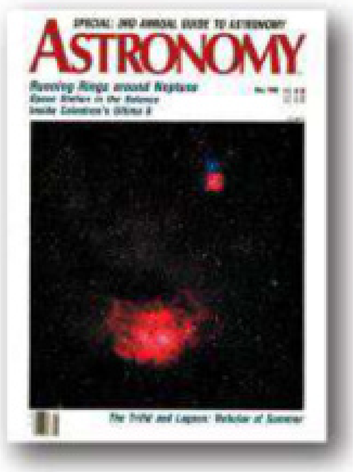
Astronomers have found 20 stars similar to the Sun that appear to be moving too fast. Seven of them are traveling so quickly, in fact, that they're on trajectories to escape the Milky Way. While scientists already know of 18 hypervelocity stars that were likely thrown out of our galaxy because of interactions with its central supermassive black hole, these newfound stars didn't originate from the galactic center. The astronomers aren't sure what kicked these stars to their extreme speeds. The discovery appeared in the January 1 issue of *The Astrophysical Journal*.

WAKEY WAKEY, ROSETTA

On January 20, scientists with the European Space Agency sent a wake-up call to Rosetta, the probe set to orbit Comet 67P/Churyumov-Gerasimenko up close in August and send a lander to its surface in November. The spacecraft is operating fine after spending 957 days in hibernation. Scientists are checking Rosetta's 11 instruments to ensure they also were unaffected by the deep sleep.

OPPORTUNITY'S ENDEAVOUR REPORT

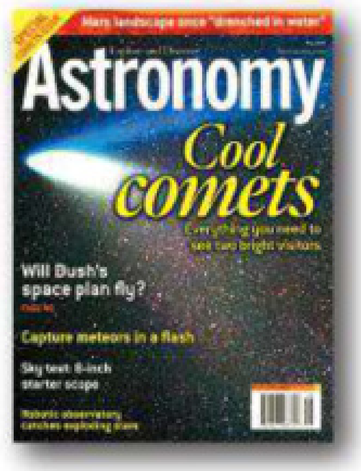
On the 10-year anniversary of the Mars Exploration Rover Opportunity's arrival at the Red Planet, scientists announced that it, along with the Mars Reconnaissance Orbiter, has found more signs of a past habitable environment. The orbiter found evidence of iron-rich smectite, a clay mineral that needs water to form, near Endeavour Crater, which Opportunity has been investigating since August 2011. According to the new results, published in the January 24 issue of *Science*, surface water existed prior to and after the crater's formation (some 3.6 billion years ago) and had near-neutral pH levels — a value important for life to thrive. — **Liz Kruesi**



25 years ago in *Astronomy*

In the May 1989 "Running Rings around Neptune," Richard Berry anticipated the Voyager 2 spacecraft's passage of Neptune — a planet whose size and distance make its details difficult to discern, even through telescopes. With Voyager 2, scientists were interested in snapping shots of the gassy planet's ring system.

Voyager revealed Neptune to have five young, dusty rings. Astronomers think they were birthed by the collision and breakup of the planet's inner (former) moons.



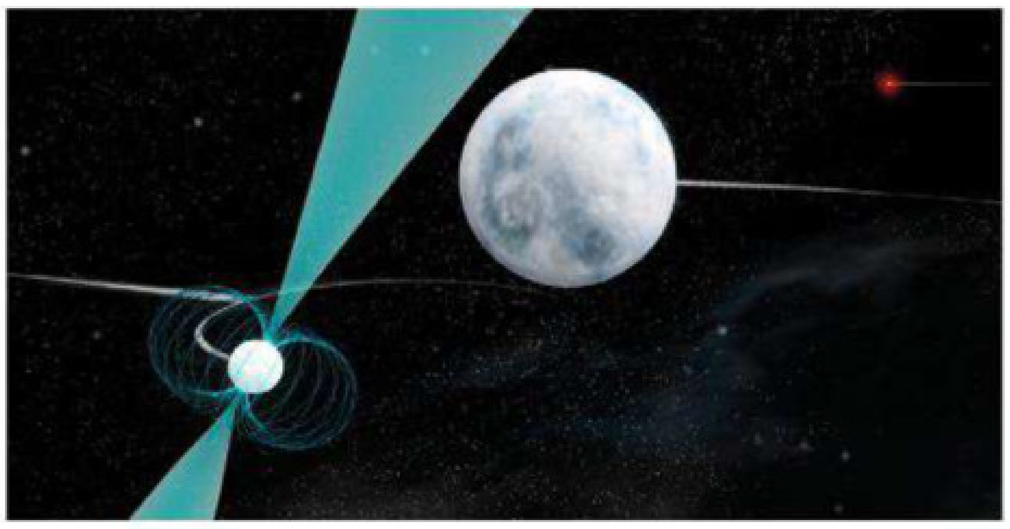
10 years ago in *Astronomy*

In the May 2004 issue of *Astronomy*, Frank Sietzen, Jr., wrote "A new vision for space," which called the feasibility of President George W. Bush's manned spaceflight plans into question. The program, Constellation, proposed sending humans to Mars via a learning-layover on the Moon, with lunar landings beginning within a decade.

President Obama canceled the budget-heavy program in 2010, proposing instead that humans in spacesuits land on an asteroid. — **Sarah Scoles**

ASTRONEWS

FAR OUT. Baby planets are five times as far from HD 142527 as Neptune is from our star, according to *Publications of the Astronomical Society of Japan*.



CLOSE QUARTERS. In a newly discovered and gravitationally intense star system, a pulsar (lower left) and a white dwarf (center) are in a tight orbit around each other. The pair is orbited by a second white dwarf (upper right), all within the space Earth's orbit takes up. BILL SAXTON/NRAO/AUI/NSF

Pulsar lives in triple system

Scientists have discovered a rapidly spinning neutron star with an unconventional living arrangement. This pulsar cohabitates with two white dwarfs, and the three are smashed together in a space smaller than Earth's orbit around the Sun. The system is gravitationally extreme, with the three members all tugging on one another. The arrangement will allow astronomers to test the limits of general relativity and find out if their theories of gravity break down in the face of such a force. The results appeared online January 5 in *Nature*.

Pulsars are the remnants of massive stars that have exploded as supernovae. City-sized but slightly more than solar-mass, they are as dense as atomic nuclei and can rotate hundreds of times per second, sending lighthouse-like beams of radiation Earth's way with each spin. White dwarfs, on the other hand, are the leftovers of average-sized stars — stellar corpses squished to Earth's radius but containing the mass of the Sun.

This pulsar's extremely regular pulses allow astronomers to measure gravitational perturbations precisely. "While Einstein's theory of general relativity has so far been confirmed by every experiment, it is not compatible with quantum theory," says Scott Ransom of the National Radio Astronomy Observatory, which operates the Green Bank Telescope, the instrument he and his team used to make the discovery. "Because of that, physicists expect that it will break down under extreme conditions."

With precise measurements of how the dead stars affect one another, the team will find out whether Einstein's century-old predictions hold up to the scrutiny of stellar systems he could not have imagined. **— S. S.**

QUICK TAKES

FOCUSED FLARE

Scientists found gravitationally lensed gamma-ray flares from 4.35 billion light-years away, scientists said January 6 at the American Astronomical Society meeting.

ACTIVE ASTRONOMY

Astronomers at the Space Telescope Science Institute used a 3-D printer to make a tactile version of open cluster NGC 602's actual shape, NASA announced January 7. They plan to expand production.

SENSORY SCIENCE

A new e-book, *Reach for the Stars*, explores the Tarantula Nebula in a multisensory way that's accessible to all. NASA provided a preview January 9 at the American Astronomical Society meeting.

DEAD AND GONE

For the first time, astronomers have seen the X-ray exhale from a dwarf galaxy's central black hole as it devoured a star, scientists said January 8 at the American Astronomical Society meeting.

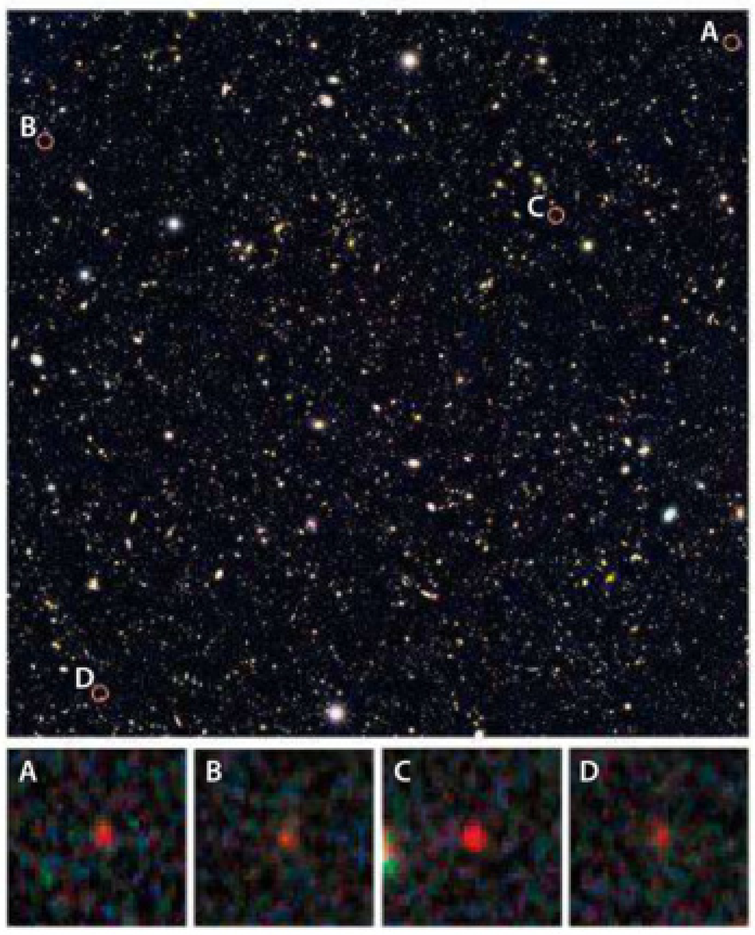
OLD GOLD

The Keck Observatory has detected a "normal" galaxy that existed just 3 billion years after the Big Bang, says a paper forthcoming in *The Astrophysical Journal*.

STRANGE SIBLINGS

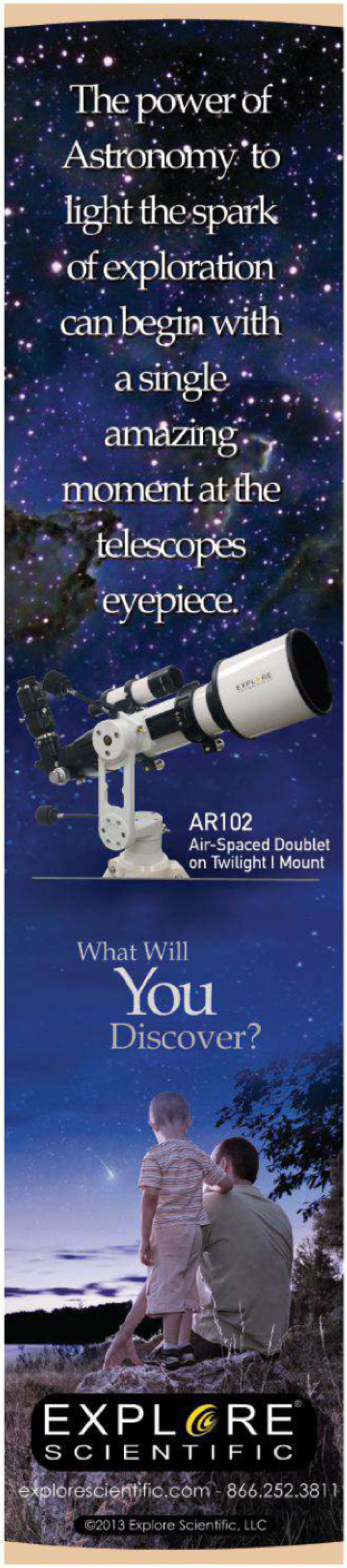
Scientists have found a black hole and a Be-type star, whose surface spins at more than 620,000 mph (1 million km/h), orbiting each other. They describe the duo in the January 16 issue of *Nature*. **— S. S.**

Unexpectedly bright galaxies found in the early universe



NASA/ESA/G. ILLINGWORTH (UCSC)/P. OESCH (UCSC; YALE UNIV.)/R. BOUWENS & I. LABBÉ (LEIDEN UNIV.), ET AL.

YOUTHFUL EXUBERANCE. Using NASA's Hubble and Spitzer space telescopes, astronomers have identified four unusually bright young galaxies in the early universe. The deep survey image shows these objects as they appeared just 500 million years after the Big Bang; surprisingly, they are about 10 to 20 times more luminous than any such stellar conglomeration observed before. Their brilliance comes from active star formation, with one producing stars at a pace about 50 times faster than our galaxy does today. For the first time, the astronomers also were able to determine such a distant object's mass: Although only some 3 percent the diameter of the Milky Way, each of these galaxies is likely home to around a billion stars. Scientists at the American Astronomical Society meeting in Washington, D.C., released this image January 7. **— K. F.**





SECRET**SKY**

BY STEPHEN JAMES O'MEARA

Saturn's opposition effect

This month, see the ringed planet in a new, brighter light.

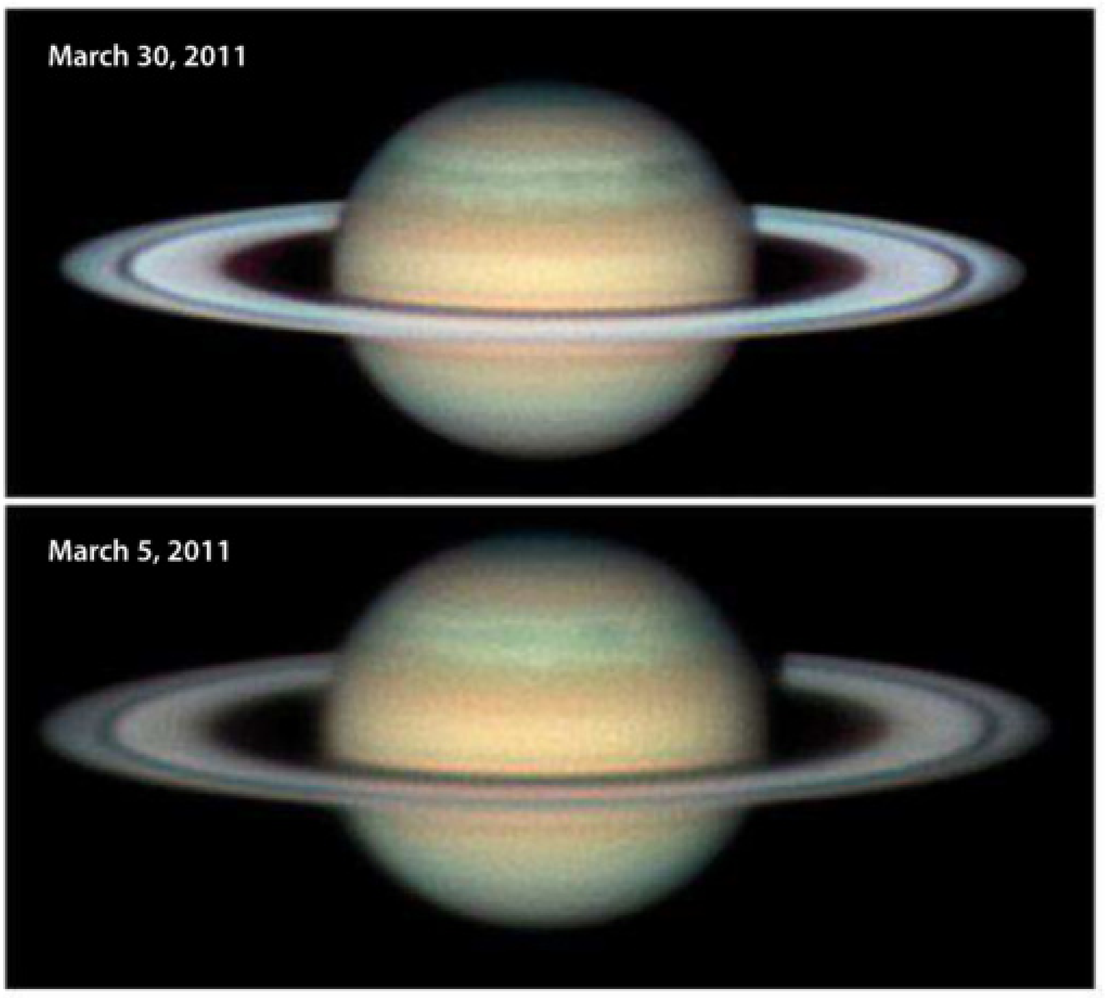
This month, Saturn reaches opposition — the point in its orbit when the planet lies directly opposite the Sun in our sky. At this time, Saturn shines more brilliantly to our eyes than at any other point this year. Through a telescope, its rings also "surge" in brightness for a couple of days around opposition, which occurs May 10 at 18h UT (see p. 62). The rings' temporary brightening is one of the most visually fascinating occurrences around Saturn. Unless you observe this planet regularly, though, you can easily overlook it.

The Seeliger effect

Generally, when you observe Saturn through a telescope before or after opposition, the rings appear about as bright as the planet's globe. For days around the time of opposition, however, the rings suddenly intensify in apparent brightness, outshining the globe before dimming back to their normal appearance.

German astronomer Hugo von Seeliger (1849–1924) first noticed this change in 1887. Because of his pioneering research into its cause, which led him to conclude that Saturn's rings were composed of tiny particles, the effect was named in this scientist's honor.

Two major physical processes lead to the Seeliger effect: shadow hiding and coherent backscattering. When we see Saturn directly illuminated by the Sun (as it is during opposition), the planet's shadow "hides" behind the globe, placing more ring surface into view. As a result, the rings appear to brighten. The same direct lighting angle also causes the shadows of individual particles in the rings to temporarily vanish, enhancing the result.



The Seeliger effect, which combines the enhancements of shadow hiding and coherent backscattering, makes Saturn's rings appear brighter the closer the planet is to being opposite the Sun, as in the top image compared to the bottom one. CHRISTOPHER GO

But that's not all. Observations of the opposition effect on Saturn's rings from the Cassini spacecraft, in orbit around the planet, reveal that "coherent backscattering" also contributes significantly to the phenomenon. This occurs when sunlight interacts with the collective particles in the planet's rings; reflections off the many irregular bits of rock and dust combine to produce a single (coherent) more intense light. This light scatters back to our eyes and makes the rings seem to brighten.

At opposition, and the days immediately surrounding it, we see the combination of these two mechanisms as a temporary surge in the overall illumination of the rings. The only way to fully appreciate the effect visually, however, is to monitor the planet and its rings for the days near that magic moment — weather permitting.

More than Saturn

We also see the opposition effect each month when we look at the Full Moon. The Sun's direct illumination causes shadows to disappear from our satellite's craters, and the light it reflects at us increases by 40 percent. Based on the irregular particles in Apollo soil samples, scientists have determined that coherent backscatter is the phenomenon's principal cause.

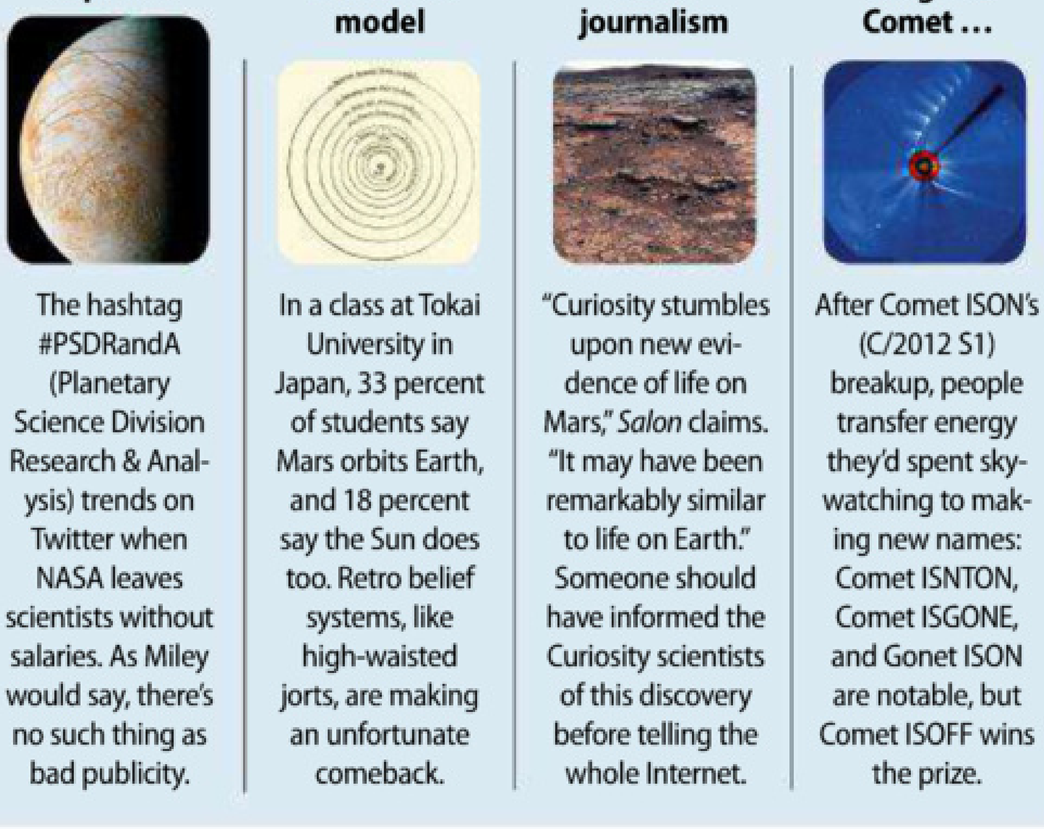
The opposition effect has a terrestrial analog as well. Known as the *heiligenschein*, this optical phenomenon is a luminous enhancement around the shadow of a person's head. It is most pronounced at low Sun angles when the surface on which the shadow falls is especially dusty or dewy. The enhancement occurs at the anti-solar point, or the spot directly opposite the Sun. Immediately around that area, the tiny particles hide their own shadows and scatter back sunlight. The word *heiligenschein* refers to the halo depicted around saints' heads and literally means "saint's light." Perhaps the painters of old had noticed this optical phenomenon.

As always, let me know what you see or don't see at sjomeara31@gmail.com.

COSMIC WORLD

A look at the best and the worst that astronomy and space science have to offer. **by Sarah Scoles**

Cold as space ← → Supernova hot



#epicfail

The hashtag #PSDRandA (Planetary Science Division Research & Analysis) trends on Twitter when NASA leaves scientists without salaries. As Miley would say, there's no such thing as bad publicity.

Geocentric model

In a class at Tokai University in Japan, 33 percent of students say Mars orbits Earth, and 18 percent say the Sun does too. Retro belief systems, like high-waisted jorts, are making an unfortunate comeback.

Yellow journalism

"Curiosity stumbles upon new evidence of life on Mars," *Salon* claims. "It may have been remarkably similar to life on Earth." Someone should have informed the Curiosity scientists of this discovery before telling the whole Internet.

Long live Comet ...

After Comet ISON's (C/2012 S1) breakup, people transfer energy they'd spent sky-watching to making new names: Comet ISNTON, Comet ISGONE, and Gonet ISON are notable, but Comet ISOFF wins the prize.

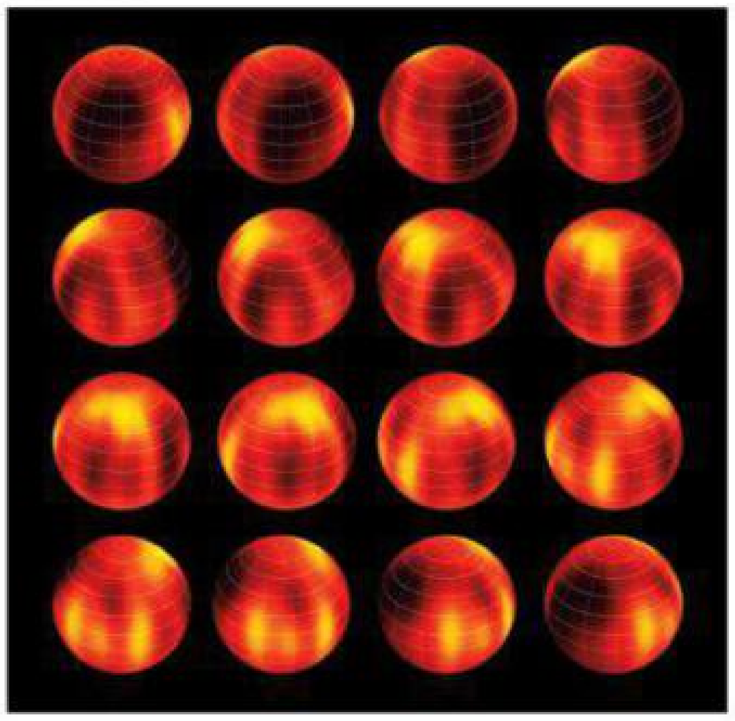
NASA/JPL/TED STRYK (#EPICFAIL); WIKIMEDIA COMMONS (GEOCENTRIC MODEL); NASA/JPL-CALTECH/MSSS (YELLOW JOURNALISM); ESA/NASA/SOHO/SDO (LONG LIVE COMET ...)

BROWSE THE "SECRET SKY" ARCHIVE AT **www.Astronomy.com/OMeara.**

BAR TIME. Galaxies grow central bars twice as often now as in the early cosmos, says a future *Monthly Notices of the Royal Astronomical Society*.

SPACE SCIENCE UPDATE

WEATHER FORECASTS ON BROWN DWARFS



GLOBAL GALES. Scientists have created the first weather map of a brown dwarf. This image sequence shows a full rotation of Luhman 16B and its changing weather. ESO/I. CROSSFIELD

Called "failed stars," brown dwarfs form with insufficient mass to fuse hydrogen into helium in their cores — a process that defines a star. But these objects aren't planets either. Instead, brown dwarfs bridge the gap between stars and planets and have masses at least 14 but no more than 80 times that of Jupiter.

Brown dwarfs slowly radiate the heat they were born with, which glows in infrared. Astronomers thus use infrared-detecting telescopes to find and examine these celestial bodies. Two studies reported in January discuss observations of these objects and focus on their changing weather.

One, announced January 7 at the American Astronomical Society meeting in Washington, D.C., concludes that most brown dwarfs have turbulent storm systems. The scientists monitored 44 brown dwarfs for 20 hours each with NASA's Spitzer Space Telescope to track brightness variations. Half of the objects exhibited such changes. "As the brown dwarfs spin on their axis, the alternation of what we think are cloud-free and cloudy regions produces a periodic brightness variation that we can observe," describes co-author Stanimir Metchev of Western University in Ontario, Canada. "These are signs of patchiness in the cloud cover."

But due to random orientations, argue the astronomers, most of those 44 brown dwarfs probably have turbulent weather patterns, and only those 20 orient in such a way that Spitzer could see atmospheric changes.

The other study appeared in the January 30 issue of *Nature*. Ian Crossfield of the Max Planck Institute for Astronomy in Heidelberg, Germany, and colleagues observed the two closest brown dwarfs to Earth — WISE J104915.57-531906.1AB (also known as Luhman 16A and 16B). At just 6.5 light-years from us, the pair is bright enough for astronomers to study in detail. Crossfield's team used a spectrograph attached to one of the units of the Very Large Telescope array to break apart the light from five-hour observations of both brown dwarfs. Because Luhman 16B's rotation period is 4.9 hours, the scientists could detect brightness variations across a full rotation. Luhman 16A, they say, rotates slower than its sibling if their spin axes are aligned.

Crossfield and colleagues focused on one specific molecule in the brown dwarfs' atmospheres — carbon monoxide — and tracked how this material moved throughout them. The astronomers identified bright and dark features on Luhman 16B, which they suggest are global patchy clouds. Crossfield's team says the bright areas are regions with less cloud cover and thus let more of the brown dwarf's interior heat through; the dark areas are regions with thicker cloud cover and therefore are cooler. The scientists interpret these brightness changes and cloud cover as part of atmospheric weather patterns, and they used these observations to create the first weather map of the brown dwarf.

Crossfield and colleagues suggest follow-up observations of additional molecule tracers in the atmosphere to see if they're mapping changes in temperature, cloud properties, or differences in carbon monoxide abundances across the globe. — **L. K.**

58 The number of galaxies revealed by the massive foreground galaxy cluster Abell 1689, which acted as a gravitational lens to magnify the light of the newly discovered objects. Scientists announced the find January 7 at the American Astronomical Society meeting in Washington, D.C.



ASTRO**CONFIDENTIAL** BY KARRI FERRON

Stellar mergers or the collapse of massive gas clouds in the early cosmos might have seeded supermassive black holes.

FAST FACT

Amy **Reines** NASA Einstein Fellow at the National Radio Astronomy Observatory in Charlottesville, Virginia



COURTESY AMY REINES (PORTRAIT); D. W. HOGG/M. R. BLANTON/THE SLOAN DIGITAL SKY SURVEY COLLABORATION/NRAO/AUI/NSF (GALAXY)

WHAT ARE DWARF GALAXIES TEACHING US ABOUT BLACK HOLES?

Over the past decade, we have come to appreciate that essentially every normal galaxy, including our Milky Way, harbors a supermassive black hole at its center. These monsters play an important role in the evolution of galaxies and the appearance of the observable universe, but their origin is largely unknown.

The growth of supermassive black holes over cosmic history appears to be linked to the buildup of their host galaxies, with more massive galaxies generally harboring more massive black holes. Therefore, finding and studying the smallest "dwarf" galaxies hosting supermassive black holes can provide clues to the origin of such behemoths.

Until recently, however, astronomers knew of very few dwarf galaxies with supermassive black holes. These enormous singularities were almost exclusively found in giant galaxies, and the very existence of supermassive black holes in dwarf galaxies was controversial.

That line of thinking is changing now, thanks in part to our new study using data from the Sloan Digital Sky Survey that has revealed more than 100 dwarf galaxies hosting supermassive black holes. The black holes are only a few hundred thousand times the Sun's mass, which is tiny in comparison to the most massive black holes that weigh in at nearly 10 billion times the Sun's mass.

While we only found signatures of "active" black holes in a tiny fraction of these dwarf galaxies, our search technique is only sensitive to the brightest and most actively feeding ones. So there are likely many more supermassive black holes hiding out in dwarf galaxies. Our ongoing complementary studies using radio and X-ray observations are already starting to unveil these hidden black holes.

Ultimately, searching for and studying supermassive black holes in dwarf galaxies will provide important clues to the puzzling question: How did supermassive black holes that reside in the center of nearly every full-sized galaxy get started in the first place?

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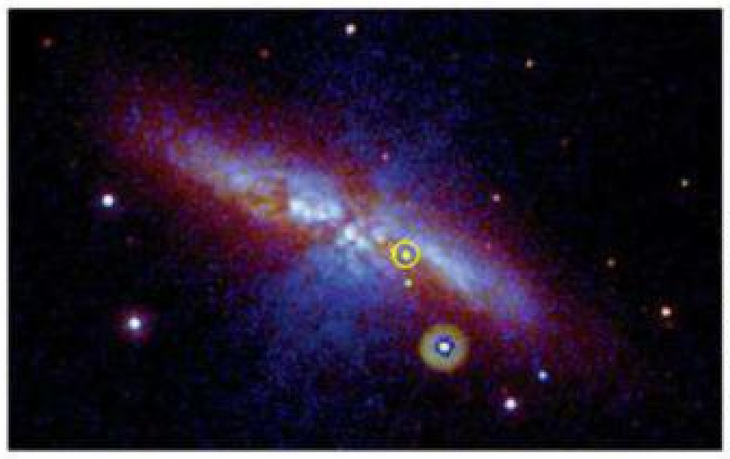


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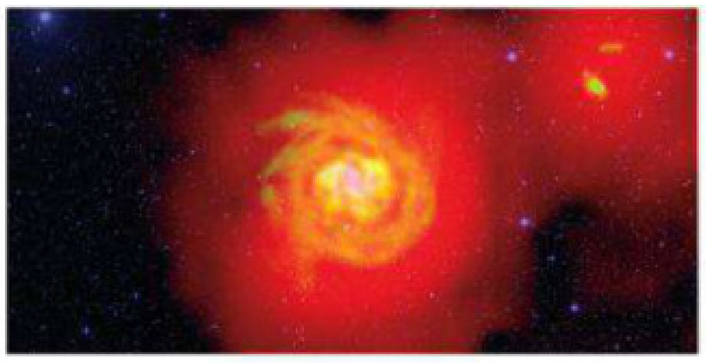


NASA/SWIFT/P. BROWN (TAMU)

Students and Swift see a new supernova

CLOSE KABOOM. Twelve million years ago, a star in the Cigar Galaxy (M82) blew up. On January 21, the light from that explosion reached the telescope at the University College London Observatory, where students and staff were doing a workshop. They were the first to discover this stellar death, the closest optical supernova in 20 years. Since that initial discovery, SN 2014J has been a favorite target for follow-ups, including the first by NASA's Swift satellite on January 24. Here, the supernova appears as a bright yellow dot near the middle of the galaxy (circled). The blue, green, and red colors each represent a different ultraviolet wavelength range. — **S. S.**

ASTRONEWS



D. J. PISANO (WVU)/B. SAXTON (NRAO/AUI/NSF)/PALOMAR OBSERVATORY – STScI 2ND DIGITAL SKY SURVEY (CALTECH)/WESTERBORK SYNTHESIS RADIO TELESCOPE

BOOM TOWN. NGC 6946 is a galaxy of many faces. Its starry center appears in optical light (blue), the hydrogen gas of the spiral arms and halo shows up in radio waves (orange), and the dim emission from the flow of star-forming hydrogen into the galaxy also comes as radio waves (red).

Green Bank Telescope spots a hydrogen river

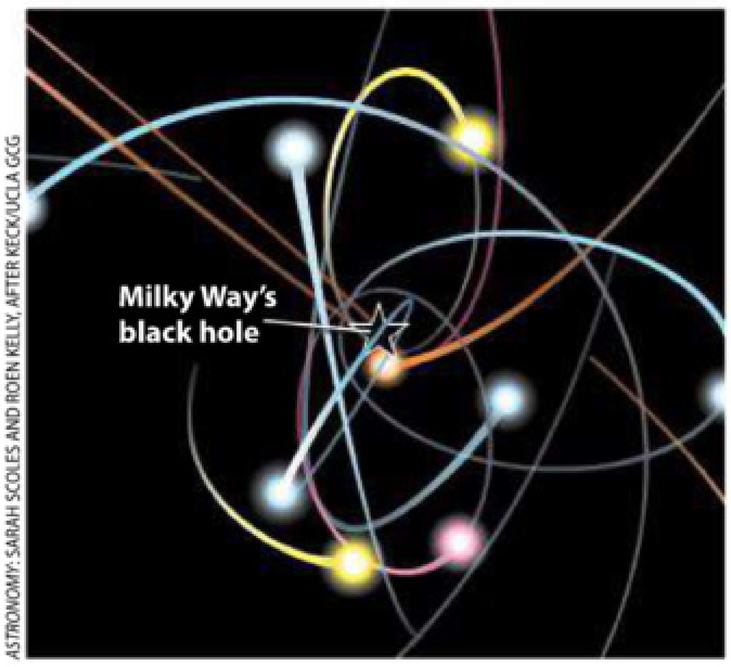
Ninety percent of the fuel needed to power galaxies' star-formation engines is missing — or, rather, scientists haven't yet found it. But using the Green Bank Telescope in West Virginia, they have begun to prove where that majority might be hiding.

A team led by D. J. Pisano of West Virginia University witnessed a filament of hydrogen streaming into the galaxy NGC 6946. This cold raw material comes from intergalactic space and helps explain why galaxies can just keep building and building stars, even after they should have used up all their original ingredients. It's the first evidence that such intergalactic space-based rivers of hydrogen — called cold flows — exist. The results appeared in the March issue of *The Astronomical Journal*. — **S. S.**

FAST FACT

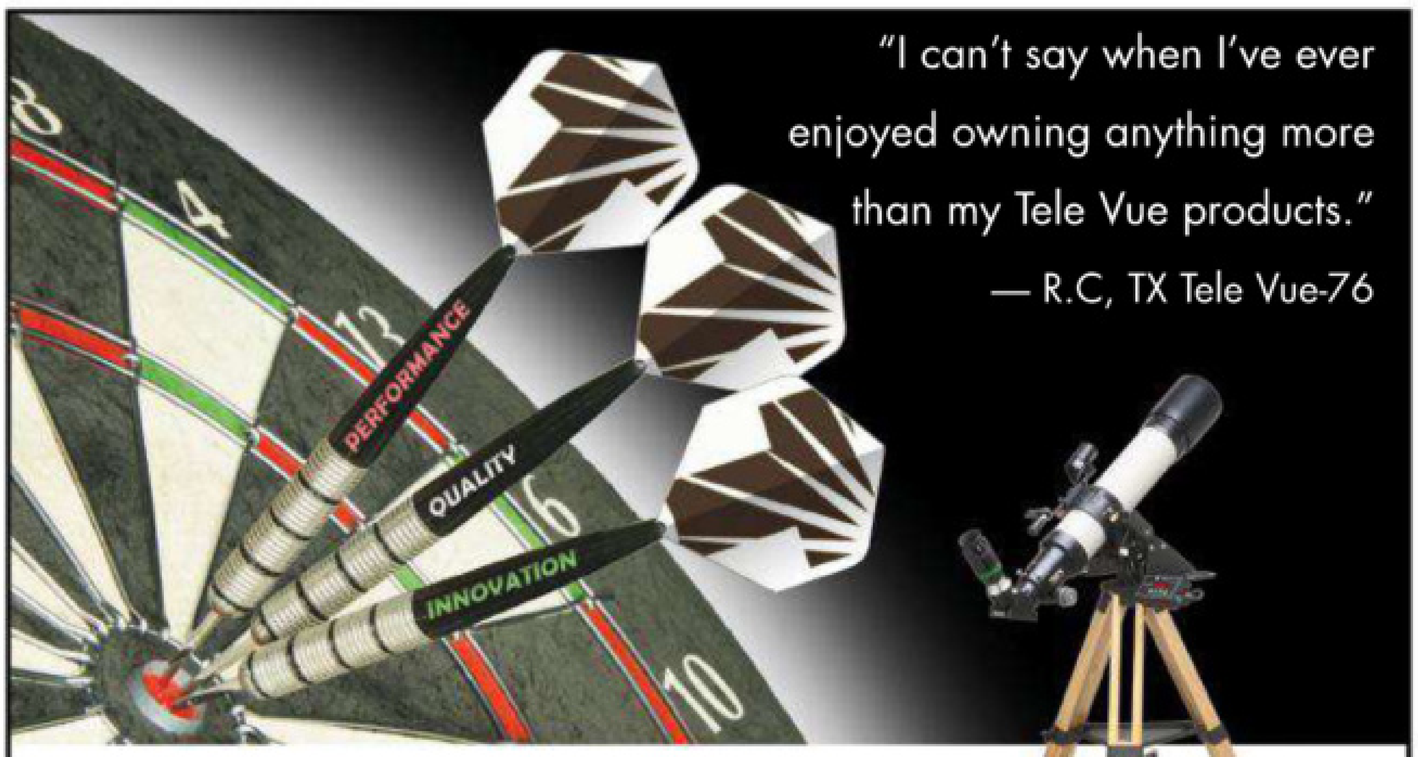
Astronomers found more young stars than expected orbiting the Milky Way's central black hole.

ORBITING A BLACK HOLE



ASTRONOMY: SARAH SCOLES AND ROEN KELLY, AFTER KECK/UCLA GCG

OBJECT OF INTEREST. While scientists cannot directly see the black hole at the center of the Milky Way, they can watch the stable of stars that orbit it. The illustration shows the paths of stars that circle within 3.3 light-years of the black hole, according to images astronomers have been snapping since 1995. From the size, shape, and length of these orbits, researchers have used astronomer Johannes Kepler's laws of motion to calculate the mass of the black hole: 4 million times that of our Sun!



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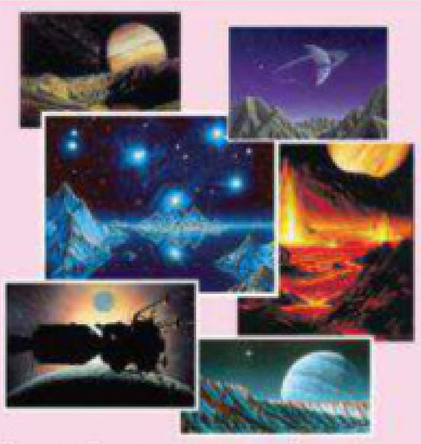
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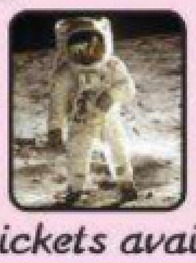
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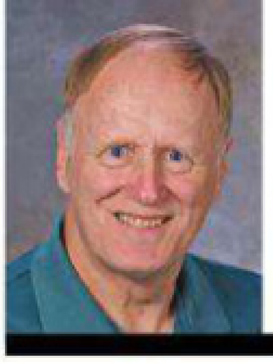
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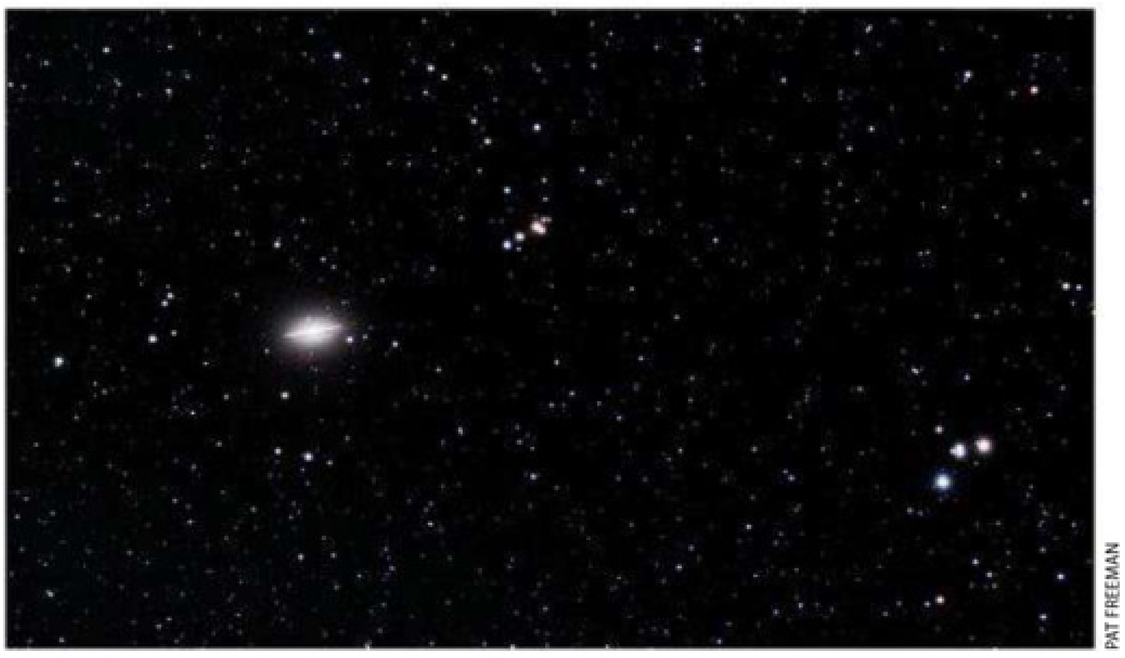


OBSERVING**BASICS**

BY GLENN CHAPLE

A hat, a shark, and time travel

Seek out some memorable objects on the Virgo-Corvus border.



PAT FREEMAN

While observing the Sombrero Galaxy (M104, far left) this spring, be sure to check out two fun stellar groupings nearby: the Jaws (upper center) and Stargate (far right) asterisms.

Happy Cinco de Mayo! What's the connection between backyard astronomy and this popular May 5 Mexican-American holiday? That's simple. We're going to the southerly part of the constellation Virgo to explore the Sombrero Galaxy (M104), one of the finest examples of an edge-on galaxy bisected by a dark dust lane. The nickname arises from its resemblance to the traditional Mexican headgear, the bright nuclear bulge forming the crown of the hat and the dust lane the wide brim.

An 8th-magnitude object with high surface brightness, the Sombrero Galaxy is visible using binoculars on a clear moonless night (a dark-sky location is a must). A small-aperture scope (like the 3-inch reflector I used for my first view of the galaxy back in 1978) reveals its elongated 7.1' by 4.4' form. The visibility of the dust lane depends on telescope aperture and sky transparency.

You can pick it out with a 4-inch scope from regions blessed with truly dark skies, but if you live in a suburban area under moderately light-polluted skies, you'll need an 8-inch or larger instrument. Even then, averted vision (looking slightly away from an object to use a more sensitive part of your eye) may be necessary. The Sombrero Galaxy fairly begs for dark skies and large aperture!

Recent observations by NASA's Spitzer Space Telescope indicate that M104 has a split personality. Traditionally, observers classified it as disk-shaped. But Spitzer's infrared eye peered through the dust lane to reveal a feature hidden from visual means — an outer halo with the right size and mass to be a giant elliptical galaxy. The Sombrero now appears to be an elliptical galaxy with a thin embedded disk. It's like two galaxies — one inside the other!

When viewing the Sombrero with a wide-angle eyepiece, you may come across two conspicuous stellar groupings to its west, one in Virgo and the other in Corvus. The first, less than ½° away, is a hockey-stick-shaped arrangement consisting of four 8th- and 9th-magnitude stars. The second, farther west and slightly south, is a striking triangle-within-a-triangle formation called the Stargate.

The blade of the hockey stick consists of the double star Struve 1664 (Σ1664), a magnitude 7.8 and 9.2 pair separated by 38". The two remaining stars, of magnitudes 8.6 and 8.9, complete the stick. This eye-catching formation also represents the gaping maw of an asterism known as "Jaws"; a row of fainter stars running northward rounds out the shark's body.

A gentle southwestward nudge of the telescope will bring the Stargate into view. Three words describe this stellar sextet: Amazing! Amazing! Amazing! A year ago, fellow Amateur Telescope Makers of Boston member Steve Clougherty introduced me to the Stargate at the club's observing field in Westford, Massachusetts. At its center is the triple star Σ1659, whose magnitude 8.0 main star forms a compact triangle with stars of magnitudes 8.3 and 11.0. The trio is nestled inside a larger triangle composed of magnitude 6.6, 6.7, and 9.9 stars. The entire formation spans an area about 5' across.

I had first seen Σ1659 more than 30 years earlier, but my 3-inch reflector failed to capture the two faintest Stargate members. Clougherty's 18-inch Dobsonian was more than adequate to bring all six stars to light. Later, I confirmed the Stargate's small-scope visibility by capturing it through a 4-inch reflector.

I find it hard to believe that the Stargate has come to the attention of backyard astronomers only in recent decades. Its present-day popularity seems to stem from an observation made by Texas amateur astronomer John Wagoner, who stumbled on it while searching for M104 in the early 1980s. To him, it looked like the "stargate" used by the science-fiction figure Buck Rogers to travel through interstellar space, hence the nickname.

Yet these nested triangles were known at least a century earlier. The Italian astronomer Ercole Dembowski (1812–1881) made measurements of Σ1659 in 1870, describing it as a triangularly arranged triple located within a large stellar triangle. Friedrich Georg Wilhelm von Struve (1793–1864), the German-Russian astronomer who discovered this triple in 1832, must have seen the surrounding triangle as well. Perhaps the Stargate wasn't as visually impressive in the narrow fields of the long-focus refractors they used as it is in the much wider fields of today's short-focus reflectors. Viewed with an eyepiece that magnifies 50x to 75x and encompasses a field at least 1° across, the Stargate seems to jump out of the surrounding darkness — a mesmerizing sight, indeed!

Questions, comments, or suggestions? Email me at gchaple@hotmail.com. Next month: We go from a spiral galaxy and a Mexican hat to a multiple star and a Civil War general. Clear skies!

FROM OUR INBOX

Picking up the habit

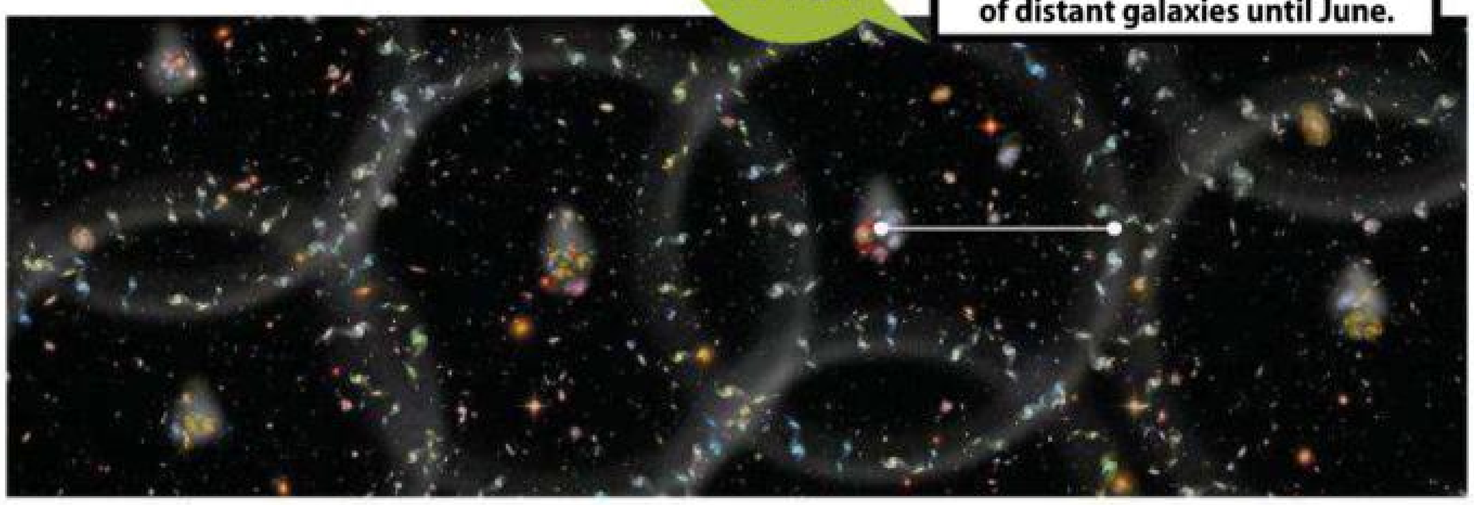
Four Christmases ago, my wife presented me with a beautiful 9.25-inch telescope, but I didn't begin to use it until last March. For a virtual beginner, columns like Glenn Chaple's in the December issue ("Fun facts for star party standouts") are more valuable than I can express. Thank you for including information for us novices. — **David Davidson,** Atlanta

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FAST FACT

The Sloan Digital Sky Survey's Baryon Oscillation Spectroscopic Survey will continue taking data of distant galaxies until June.



DENSITY PATTERN. Cosmic structure follows a pattern initiated by density waves — or acoustic oscillations — in the early universe. Galaxies tend to bunch along spherical shells (exaggerated in this illustration), a result of when baryonic matter (protons and neutrons) separated from radiation just 370,000 years into the universe's history.
ZOSIA ROSTOMIAN, LAWRENCE BERKELEY NATIONAL LABORATORY

Precise distances to 1 million galaxies

Astronomers using the Sloan Digital Sky Survey's Baryon Oscillation Spectroscopic Survey (BOSS) have made the most precise measurements — within 1 percent — of galaxy positions nearly halfway across the visible universe. The newest measurements, announced January 8 at the American Astronomical Society meeting in Washington, D.C., tell scientists how the universe's rate of expansion has changed.

The scientists studied baryon acoustic oscillations (BAOs). These arose in the universe's earliest moments, when a hot fluid-like mix of photons, electrons, baryons (protons and neutrons), and dark matter filled the cosmos. The gravity associated with denser regions pulled in more material, which then compressed and heated up. Radiation pressure pushed the baryons and light outward to make each region less dense. The baryon-radiation mixture expanded as a spherical sound wave (a BAO), similar to waves rippling on a pond's surface after you drop a pebble.

Some 370,000 years into cosmic history, the universe cooled enough for the electrons and baryons to combine, which allowed the radiation to stream free, carrying with it the oscillation pattern. The longest sound wave imprinted in the radiation is the farthest distance one of those pressure waves could have reached from the Big Bang in the finite time of 370,000 years. Matter clumped along the spherical BAO oscillation shells and eventually evolved into galaxies. Scientists now see these shells with a radius of about 150 megaparsecs, or 490 million light-years.

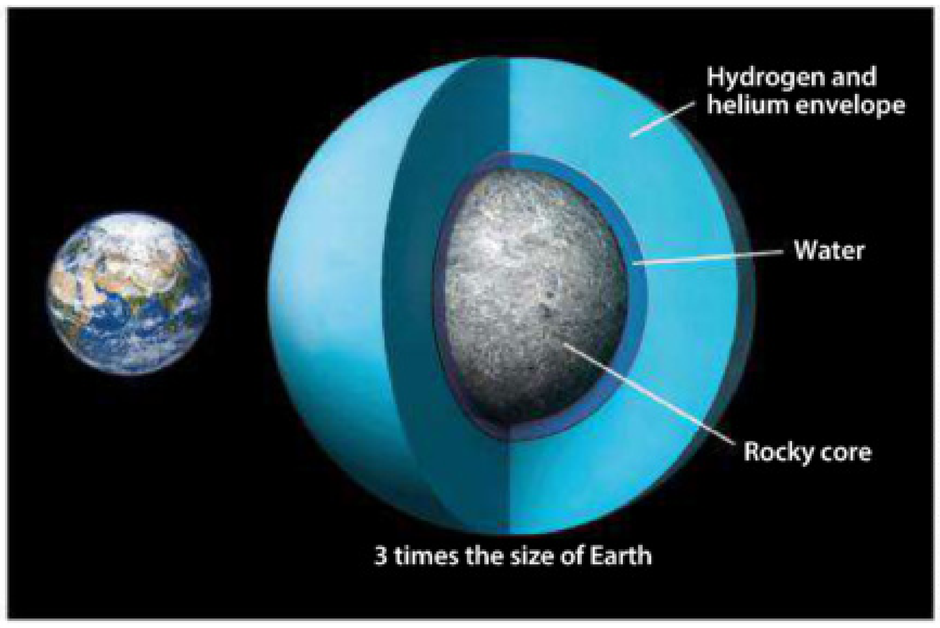
Astronomers with BOSS mapped roughly 1 million galaxies in two different epochs: when the universe was about 8 billion and 10 billion years old. They analyzed galaxy distributions, which result from BAOs, and measured the patterns (via angle on the sky) at different times in the universe's history. Because scientists already know the physical size of those shell patterns, they can calculate how far away from Earth those structures are. From that calculation, they can determine the universe's expansion rates at those different cosmic epochs. And this information gives astronomers hints about the mysterious "dark energy" that is causing the expansion. **— L. K.**





AERIAL ACHIEVEMENT. NASA's super Trans-Iron Galactic Element Recorder, which studies cosmic rays, broke the record for the longest flight of any heavy-lift scientific balloon January 4 after a 55-day deployment.

A galaxy of super-Earths and mini-Neptunes



ASTRONOMY: ROEN KELLY, AFTER GEOFF MARCY

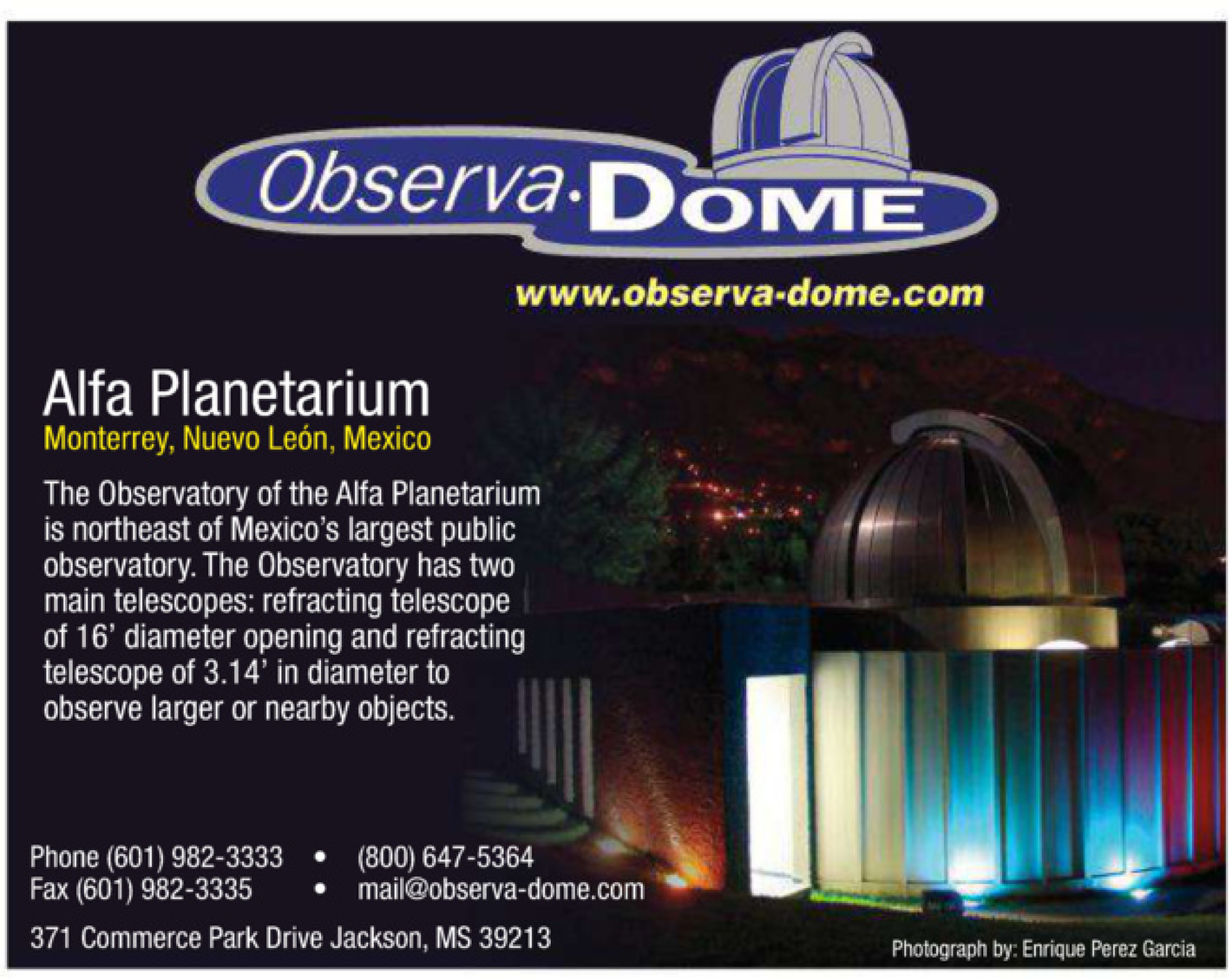
EXOPLANET DIVERSITY. More than 75 percent of Kepler's potential planets (if all these worlds exist) are super-Earths or mini-Neptunes, say astronomers. These planets range from about 1.25 to 4 times the size of Earth. This illustration compares Earth to a 3-Earth-width mini-Neptune.

Although NASA's Kepler space telescope hasn't been operational since mid-2013, scientists are still revealing evidence of exoplanets in the craft's archival data and trying to confirm the more than 3,500 candidate worlds it had uncovered. Researchers announced a number of discoveries in the Kepler data January 6 and 7 at the American Astronomical Society (AAS) meeting in Washington, D.C., including the fact that more than three-quarters of the candidate planets have sizes between that of Earth and Neptune.

Kepler observations tell scientists how much of a host star's light a planet blocks, which corresponds to that planet's diameter and orbital distance. But those data don't say anything about the planet's mass. To glean this information, astronomers study how the planet gravitationally tugs on its star with a technique called the "radial velocity" method. And if at least two worlds orbit a star, astronomers can measure how those planets tug on each other; this method is called "transit timing variation."

At the AAS meeting, many teams of astronomers reported masses calculated using these two techniques. Once they know a planet's diameter and mass, scientists can calculate its density, which gives them hints about that world's composition. From this information, astronomers suggest that the planets with sizes between Earth's and Neptune's fall into two categories: super-Earths, which have compositions similar to the four inner planets in our solar system, and mini-Neptunes, which have rocky cores surrounded by thick envelopes of hydrogen- and helium-rich materials.

Geoff Marcy of the University of California, Berkeley, and colleagues focused on 42 Kepler planet candidates orbiting 22 stars. They announced at the AAS meeting and in the February issue of *The Astrophysical Journal Supplement Series* that the line dividing super-Earths and mini-Neptunes falls somewhere between 1.5 and 2.0 Earth widths. Planets larger than that gain most of their girth through thick atmospheres instead of heavy rocky innards. — **L. K.**



FAST FACT

Open cluster M67 is 3.5 to 4.9 billion years old; our Sun is about 4.6 billion years old.



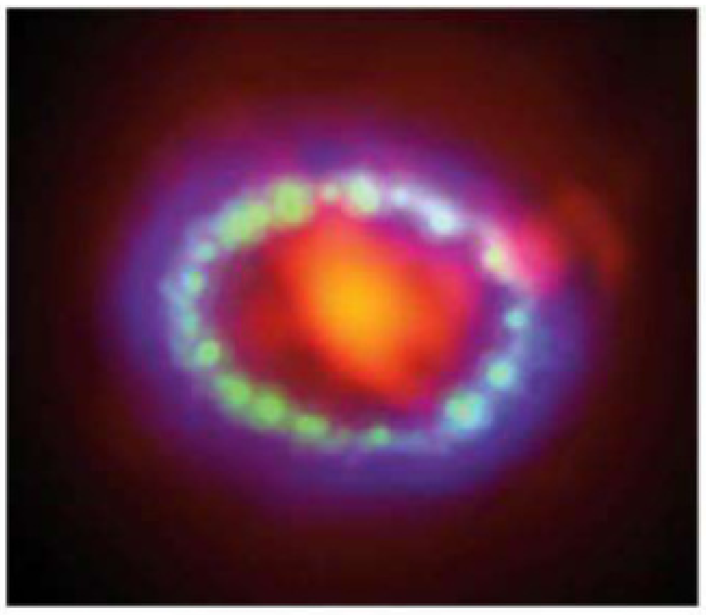
STAR CLUSTER STUDIES. Astronomers investigating M67 have discovered three new exoplanets in the open cluster, one of which is shown in this artist's impression. ESO/L. CALÇADA

Star clusters harbor planets

Astronomers have discovered more than a thousand exoplanets thus far, but most they've found orbit single or binary stars isolated from other suns. They have uncovered few in dense star clusters, which begged the question: Does the environment of a star cluster hinder planet formation? To begin to find the answer, researchers spent six years searching for signs of exoplanets in open cluster M67, which lies 2,500 light-years away in Cancer the Crab. Their results appeared in the January issue of *Astronomy & Astrophysics*.

The astronomers detected three new exoplanets in the cluster. The first has a mass of at least 1.5 Jupiters and orbits its red giant host star in 121.7 days, and the second has 40 percent of Jupiter's mass and circles its Sun-like star in 5.1 days. The third discovery was the most unusual, though: a 0.34-Jupiter-mass world that orbits in 6.9 days its solar twin host — one of the most Sun-like stars discovered to date and the first in a cluster to harbor a planet. The three new worlds indicate that star clusters don't hinder planet formation, as early reports had once stated. "These new results show that planets in open clusters are about as common as they are around isolated stars — but they are not easy to detect," says co-author Luca Pasquini of the European Southern Observatory in Germany. — **K. F.**

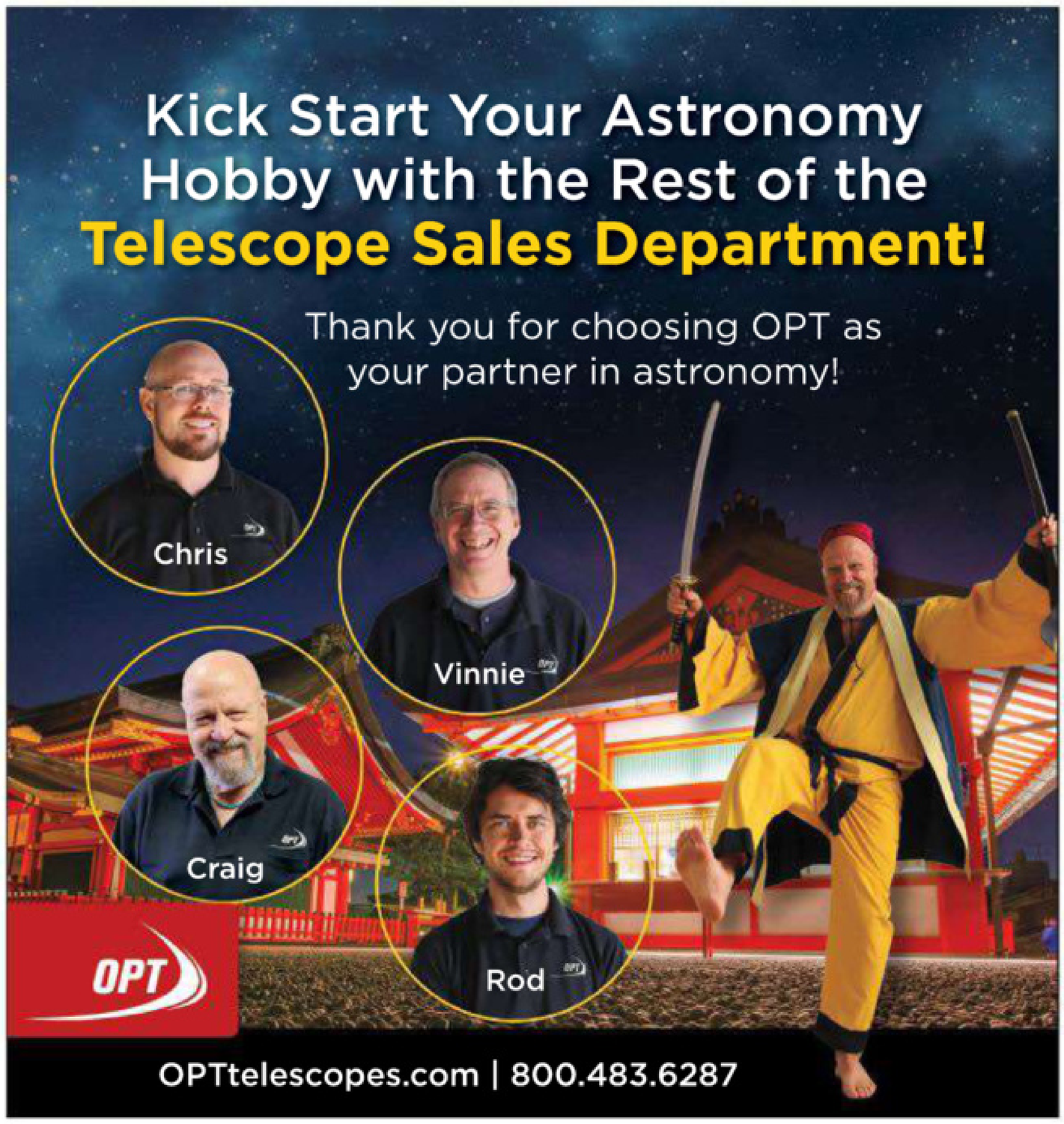
3 The number of near-Earth objects the reactivated Wide-field Infrared Survey Explorer mission discovered in its first 25 days. It detected another 854 already-known objects in that time frame.



RADIO: ALEXANDRA ANGELICH (NRAO/AUI/NSF); OPTICAL: NASA HUBBLE; X-RAY: NASA CHANDRA

Nearby dust factory

DUST CROP. The nearest supernova to Earth in more than 400 years, Supernova 1987A provides astronomers with an excellent laboratory. A team of scientists used the Atacama Large Millimeter/submillimeter Array (ALMA) to look for dust at the site of SN 1987A. While a study in 2011 showed this material in the general location of the supernova remnant, the ALMA observations pinpointed the exact position of this newly formed dust: in the cold remnants of the star's once-core. The astronomers also determined that SN 1987A created about 0.23 solar mass of dust, thus proving that supernovae can create this material. They reported the discovery January 6 at the meeting of the American Astronomical Society in Washington, D.C. In this image, red represents the radio data, green optical, and blue X-ray. — **L. K.**





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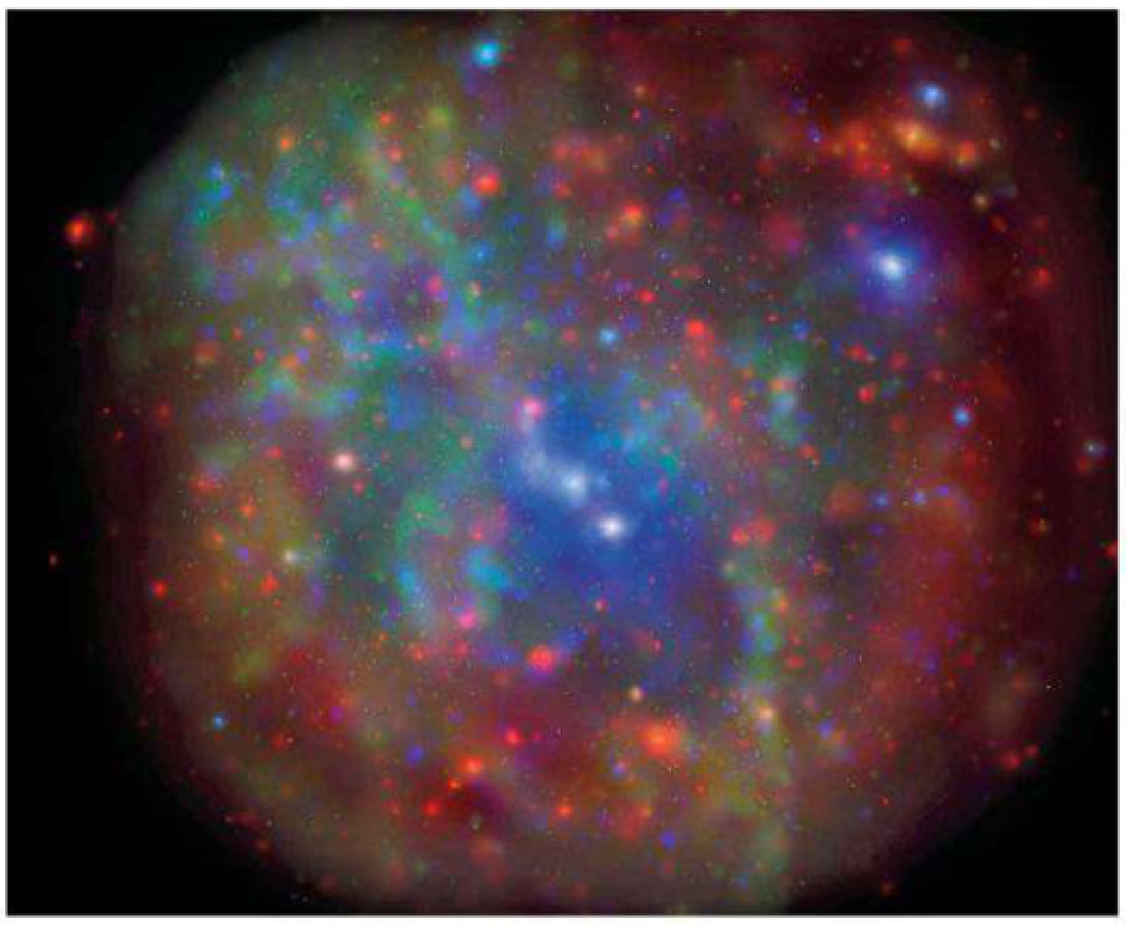
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DOUBLE TAKE. Scientists reported January 8 at the American Astronomical Society meeting that two supernovae in NGC 6984 may be related.



KEEPING WATCH. The Swift telescope has monitored the galactic center since 2006. This image merges data from all of 2013, showing the objects and regions that were consistently bright in X-rays as well as the objects and regions that produced X-ray flares. Sagittarius A*, our supermassive black hole, is in the center. G2, a cloud of gas approaching the black hole, is not yet visible, but scientists hope it will be soon. NASA/SWIFT/N. DEGENAAR (UNIV. OF MICHIGAN)

G2 has a date with a black hole

The black hole at the center of our galaxy, a 4-million-solar-mass monster called Sagittarius A* (pronounced "A-star"), is about to have a close encounter with a mysterious object called G2. Astronomers discovered fast-moving G2 in 2011 and, upon calculating its trajectory, realized it would swim right up to Sagittarius A*.

They began hoping for a fireworks show. As matter gets closer to a black hole, gravity causes it to whiz faster and run a fever, heating up and emitting high-energy radiation. Sagittarius A*'s radiation is usually thousands of times dimmer than astronomers might expect it to be. Because it does not have much food to eat, it does not heat that nonexistent food to extreme temperatures.

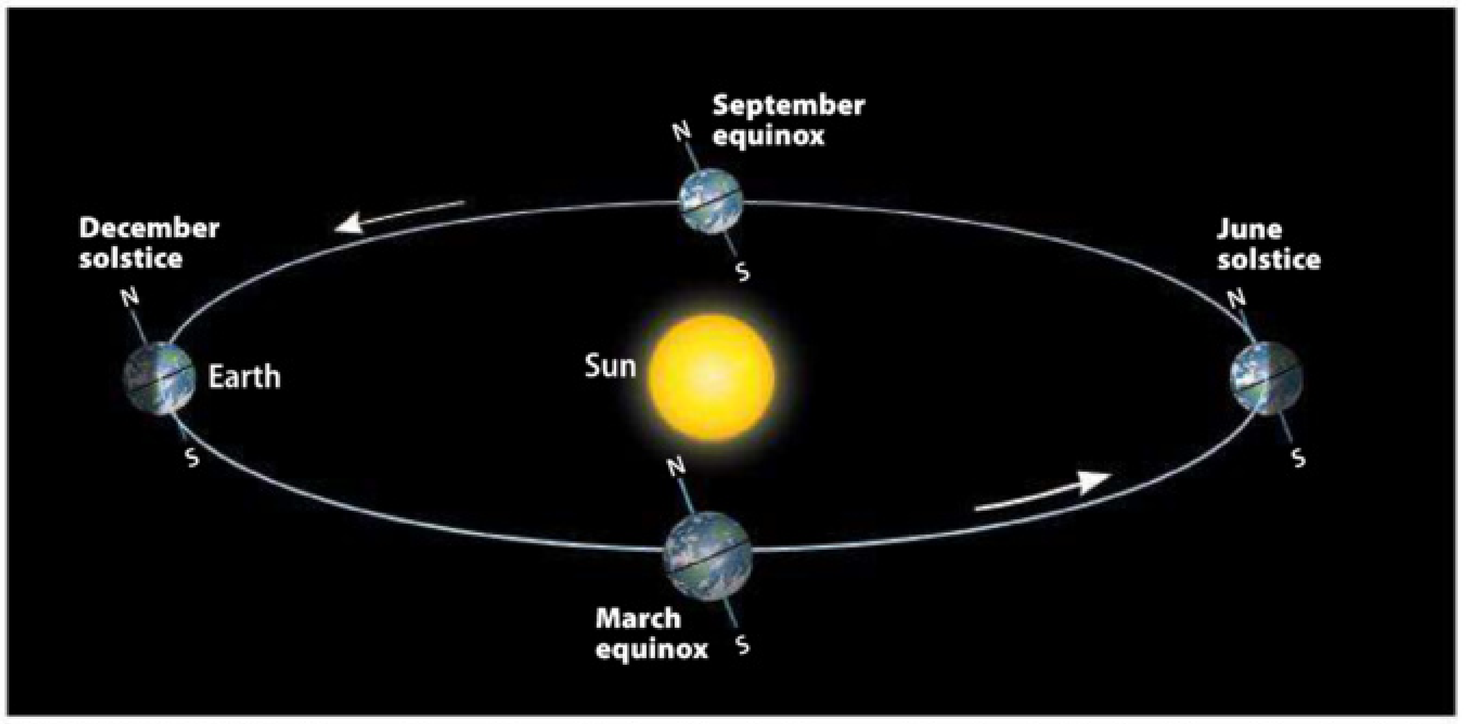
But now that the snack-sized G2 — three times Earth's mass — is nearby, astronomers have telescopes trained on it, in anticipation of a potential light show. NASA's Swift telescope, for instance, is taking pictures of the region daily. That is how fast things could change for G2, and they do not want to miss a single frame in its autobiographical movie.

On January 8 at the American Astronomical Society's meeting in Washington, D.C., scientists from the Swift monitoring program, which has been in place as an every-few-days look at the galactic center since 2006, said that G2's appearance is important because our supermassive black hole is the only one close enough to study. And the only way to study black holes is to watch them interact with nearby material. — **S. S.**

WHY DO WE HAVE SEASONS?

Our planet's axial tilt, known as its obliquity, currently stands at 23.437458°.

FAST FACT



TILT-A-WHIRL. This diagram shows that, as Earth orbits the Sun, our planet's axis (the line through both poles) always points in the same direction. The Sun's rays fall more directly on the Northern Hemisphere during June and south of the equator during December. *ASTRONOMY*: MICHAEL E. BAKICH AND ROEN KELLY

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Chandra X-ray observations (blue) and Very Large Array radio data (red-orange) of M87 reveal how jets emanating from the central supermassive black hole create bubbles and shock waves that heat the surrounding gas.

X-RAY: NASA/CXC/KIPAC/N. WERNER, ET AL.; RADIO: NRAO/AUI/NSF/F. OWEN

Peering inside a MONSTER GALAXY

X-rays tell an explosive tale about the inner workings of M87 — a giant elliptical galaxy in the Virgo cluster that ranks among the most massive in the local universe. **by Steve Nadis**

On July 23, 1999, astronauts aboard the Space Shuttle *Columbia* deployed the Chandra X-ray Observatory. The orbiting telescope had a broad but simple charter: To gather X-ray emissions from some of the hottest and most exotic objects in the universe. Likely targets included the centers of galaxy clusters, the neighborhoods of black holes, and the regions around exploding stars — places where matter routinely reaches temperatures of millions of degrees. With superb angular resolution and greater sensitivity to faint sources than any previous X-ray telescope, Chandra would explore these environments with unprecedented clarity and power.

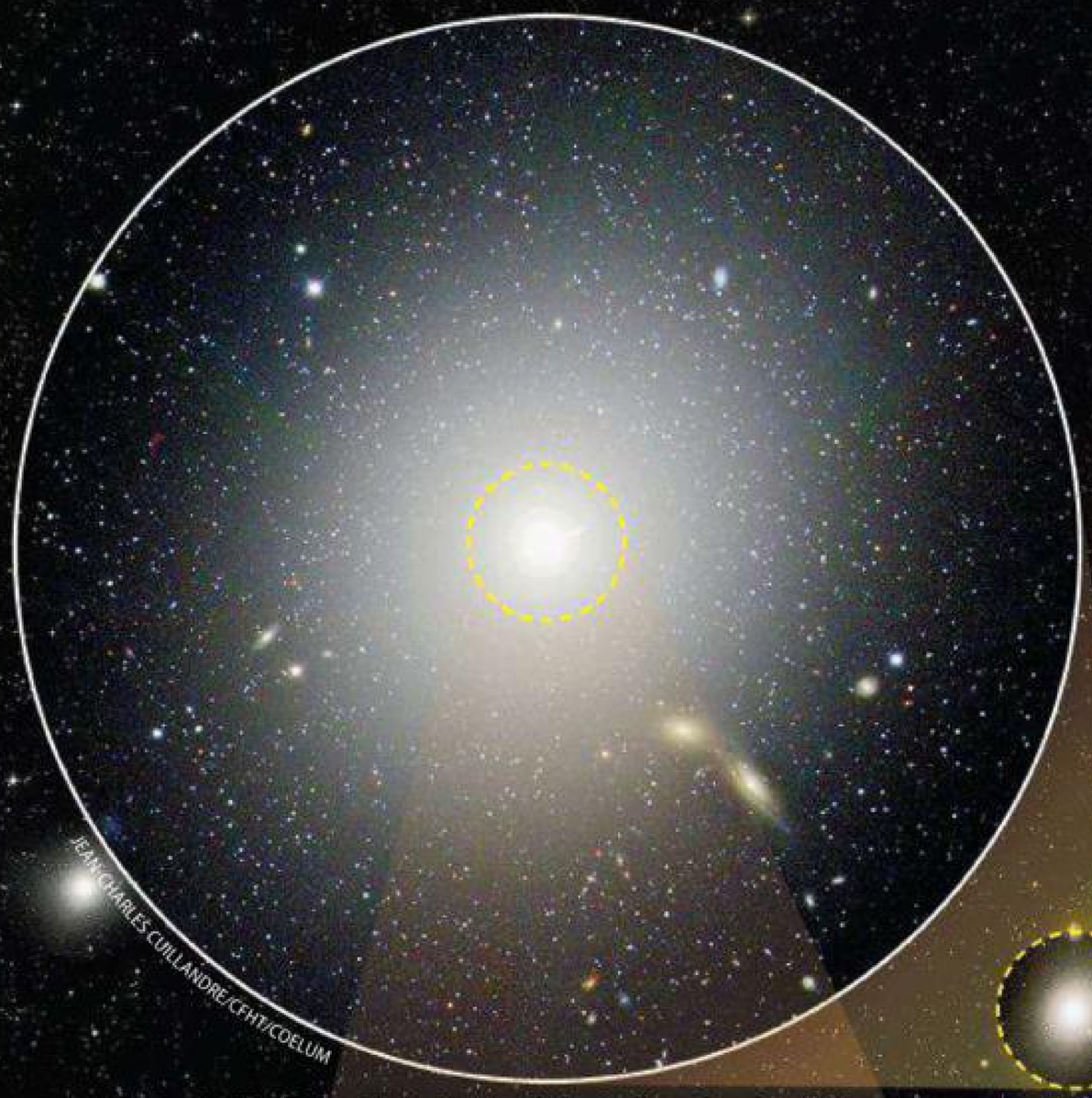
Although the observatory wasn't designed to look at a specific galaxy or cluster, Chandra is especially well suited for observing M87. This giant elliptical galaxy lies at the center of the Virgo galaxy cluster and harbors a gargantuan black hole with a mass of about 6 billion Suns. It also qualifies as an active galaxy — a highly luminous galaxy that radiates strongly across a broad range of wavelengths from a compact region at its core, the so-called "active galactic nucleus" (AGN).

As giant ellipticals go, M87 is relatively nearby — around 50 to 55 million light-years from Earth — which makes it the closest active galaxy that resides inside a large gas-filled cluster. Moreover, given that its X-ray emissions fall into an optimal temperature and energy range (of approximately 1 to 2 million kelvins [1.8 to 3.6 million degrees Fahrenheit]) for Chandra's instruments, M87 has been an ideal system for studying interactions between a supermassive black hole and its surrounding gas.

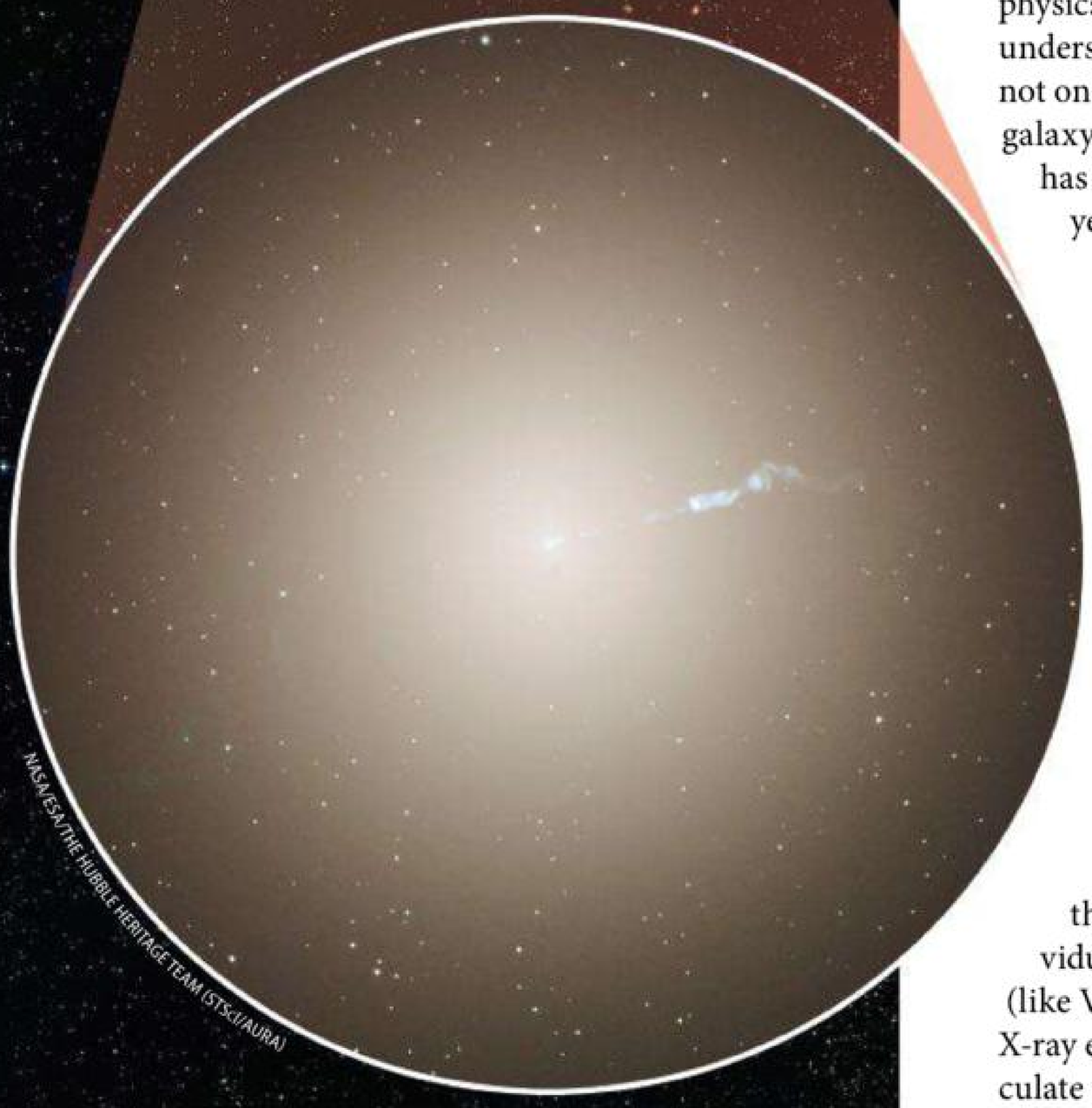
William Forman, an astrophysicist based at the Smithsonian Astrophysical Observatory (SAO) in Cambridge, Massachusetts, has focused on this galaxy

Astronomy *Contributing Editor* **Steve Nadis** *is co-author of* A History in Sum: 150 Years of Mathematics at Harvard (1825–1975)*, published by Harvard University Press in November 2013.*

The Virgo cluster holds more than 1,000 galaxies, making it the nearest large galaxy cluster to Earth. The giant elliptical galaxy M87 (circled at lower left) lies near the cluster's center; the almost equally impressive M84 and M86 dominate Markarian's Chain (right). ESO/DSS2



In visible light, M87 shows all the hallmarks of an older galaxy: ancient reddish stars and an almost total lack of the interstellar gas and dust needed to create new suns. Its surrounding halo harbors roughly 15,000 globular clusters.



The Hubble Space Telescope reveals the central regions of M87 and its bluish jet of high-speed charged particles. The jet originates near a supermassive black hole at the galaxy's center and extends some 5,000 light-years.

for decades. Working with fellow SAO astrophysicist Christine Jones, Eugene Churazov of the Max Planck Institute for Astrophysics in Garching, Germany, and others, he has been trying to understand how the supermassive black hole at the heart of M87 not only affects its environment but perhaps even controls it. The galaxy has rewarded the team for its long-running efforts. "M87 has told us a good story," Forman says, noting that the tale has yet to be recounted in full.

Red and dead

Astronomers classify M87 as an early-type galaxy — a category that includes ellipticals and S0 galaxies, which are a cross between ellipticals and disk-shaped spirals. Reddish in hue and populated by older, low-mass stars, ellipticals tend to show little ongoing star formation. Spirals are bluer, exhibit more star formation, and, as you might guess, possess stars that are younger, on average. Astronomers have long puzzled over why galaxies like M87 create new stars so anemically. In other words, Forman asks, "Why are these galaxies 'red and dead'?"

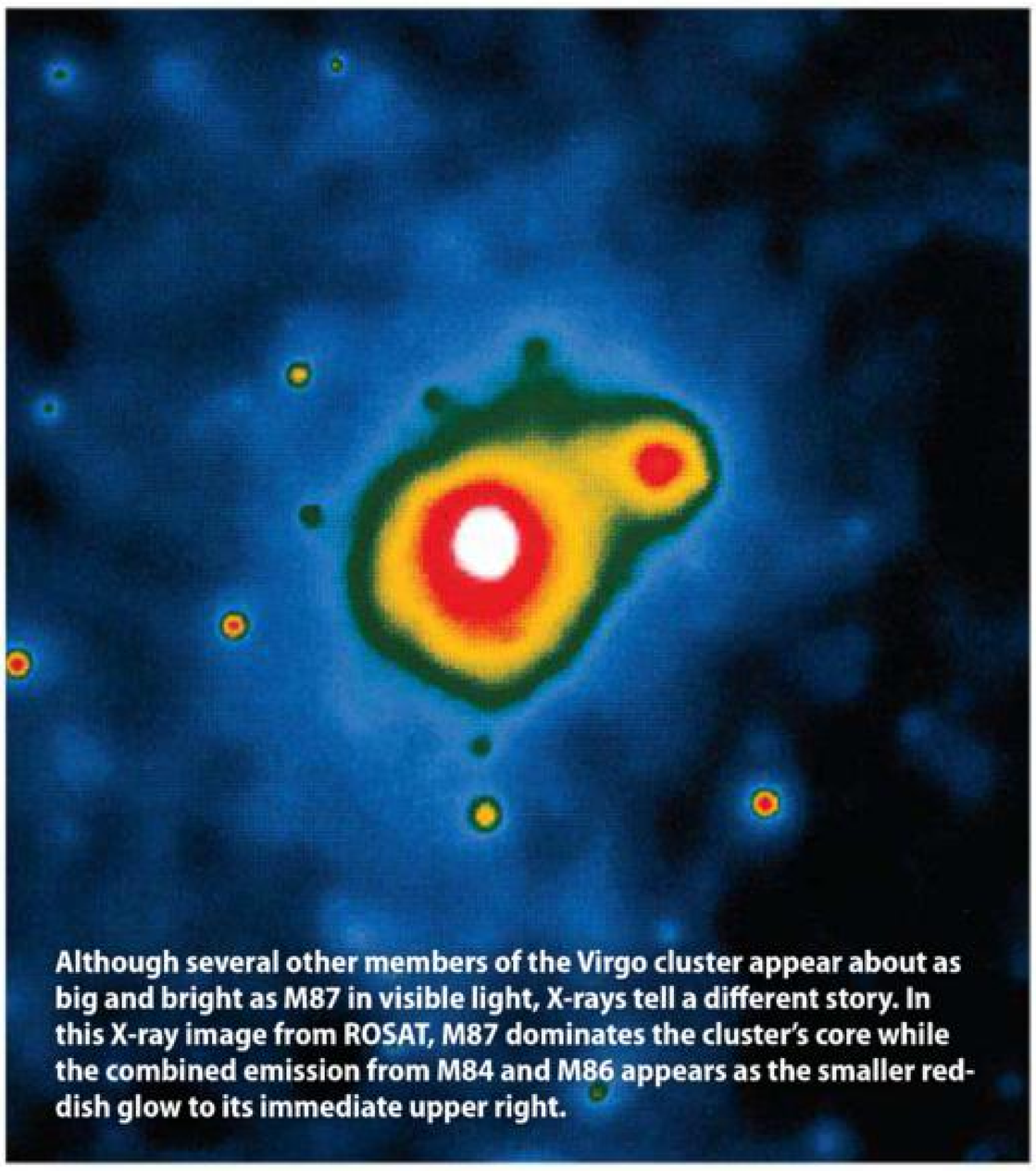
A more general version of this question has been kicked around for a couple of decades. Commonly referred to as the "cooling flow problem," it can apply not only to an individual elliptical galaxy (like M87) but also to the cluster core (like Virgo's) in which a galaxy resides. Based on the amount of X-ray energy that the Virgo cluster radiates, astronomers can calculate that some of the cluster's gas should cool enough to collapse and generate new stars.

The observed cooling rate implies that astronomers should expect to see some 20 solar masses' worth of stars forming each year, but they detect only about one-tenth as much star production. Observations from Chandra and other X-ray instruments, combined with data from radio telescopes such as the Very Large Array

(VLA) in New Mexico, provided the key insights that helped solve the cooling flow problem.

So, how does the Virgo cluster manage to keep the gas hot and thus prevent stars from forming? After many failed attempts to find concealed reservoirs of cool gas, astronomers surmised that the cluster must contain a hidden energy source. By the early 1990s, theorists had settled on a prime suspect: a supermassive black hole at the center of one of the cluster's members. Such a beast could generate enough energy in the form of periodic outbursts to prevent the surrounding gas from cooling.

Earlier Chandra studies of other systems, including the more distant Perseus cluster, had strongly hinted that this would be the case. But thanks to the observatory's close-up views of M87 during the past decade, Forman says, "People saw the effects of the outbursts and concluded that [M87's] black hole was, indeed, keeping the gas hot." A small amount of matter falling onto the black hole fuels these periodic explosions, creating powerful jets that shine brightly in the radio part of the spectrum. The fast-moving electrons, protons, and other charged particles that make up the jets ultimately heat the gas.



Although several other members of the Virgo cluster appear about as big and bright as M87 in visible light, X-rays tell a different story. In this X-ray image from ROSAT, M87 dominates the cluster's core while the combined emission from M84 and M86 appears as the smaller reddish glow to its immediate upper right.

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The quasar connection

Contrast this output with a distant young galaxy in the early, or high-redshift, universe. Such a galaxy typically experiences rapid growth, and its central black hole can feed voraciously as its gravity pulls in gas, dust, and anything else that comes too close. This material speeds up as it approaches the black hole and grows so hot that it glows brightly. In the process, the black hole temporarily may become a quasar — the most luminous type of AGN. Although quasars also possess jets consisting of hot ionized gas, or plasma, that can travel at close to the speed of light, they emit almost all of their energy in the form of electromagnetic radiation.

Once the rate of feeding, or "accretion," drops below a critical value, the quasar phase ends. The black hole's neighborhood becomes much dimmer, and most of the galactic core's energy spews out in the jets — a form of kinetic, or mechanical, energy. These jets can extend for thousands, if not hundreds of thousands, of light-years. "The power of these jets can be a thousand times greater than that in radiation," Forman says. "And that's what we're seeing in the low-redshift universe."

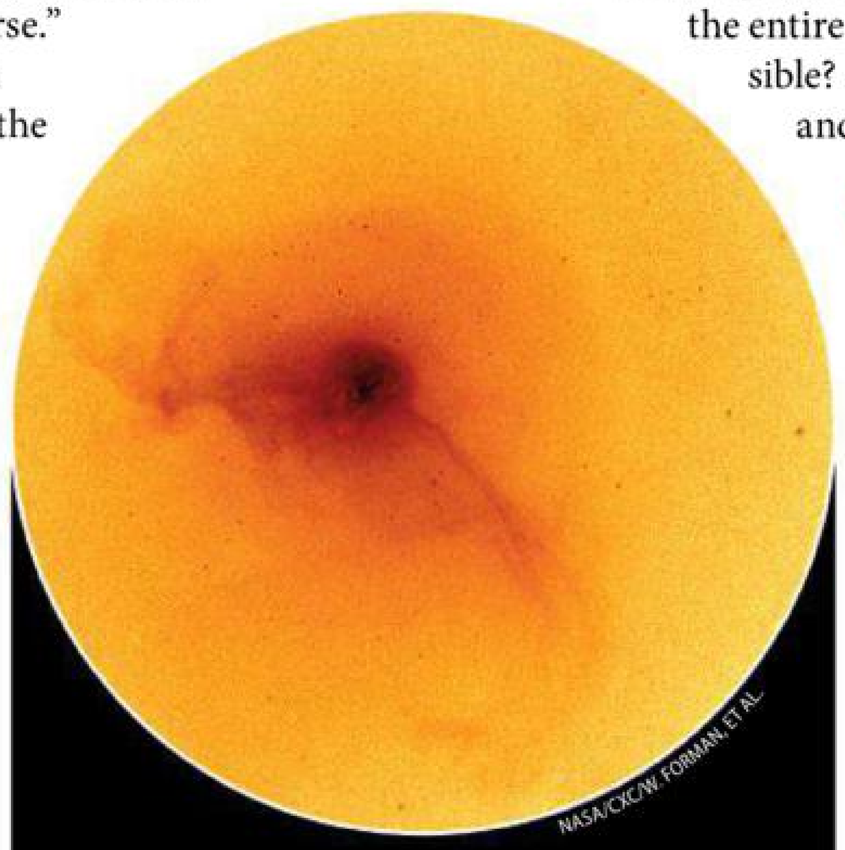
Accreting black holes drive all AGNs. In describing the transition that occurs when the AGN engine's output switches from radiation to kinetic energy, Forman draws an analogy to America's national pastime: "When a baseball is hit by a bat, it carries considerable kinetic energy but radiates little energy. In the same way, M87's jets radiate little energy but carry 1,000 times more mechanical energy."

A variety of processes transforms the jets' mechanical energy into heat, but the large blanket of hot gas surrounding the black hole plays a key role. Before the advent of X-ray astronomy, Forman says, "People didn't know there was a hot corona [or atmosphere] around the core of clusters and around bright elliptical galaxies like M87."

He again compares the situation to baseball: Early-type galaxies are like a baseball team, and its central black hole is the batter. Sometimes the batter hits the ball. And like the sporadic outbursts from a black hole, these batted balls are not the same but come as singles, doubles, triples, and home runs — or outs. Meanwhile, the corona is like the fielders, whose job is to capture the black hole's output. "The fielders are critical to this picture," Forman contends. "If there were no fielders and galaxies had no coronas, there would be no energy capture."

This still raises the question of how an exceedingly massive but physically small black hole (roughly the size of our solar system, with a radius of about 12 billion miles [20 billion kilometers]) can heat a volume of gas with a radius tens of millions of times larger.

"That's equivalent to something the size of my fist heating the entire Earth," says Forman. "How is this possible? At first people could not believe this notion and dismissed it outright."



NASA/CXC/W. FORMAN, ET AL.

The Chandra X-ray Observatory's view of M87 reveals a bright central jet surrounded by luminous arcs and dark cavities in the galaxy's multimillion-degree corona (or atmosphere) near the center. Faint rings appear about 50,000 light-years from the center and bright plumes extend even farther.

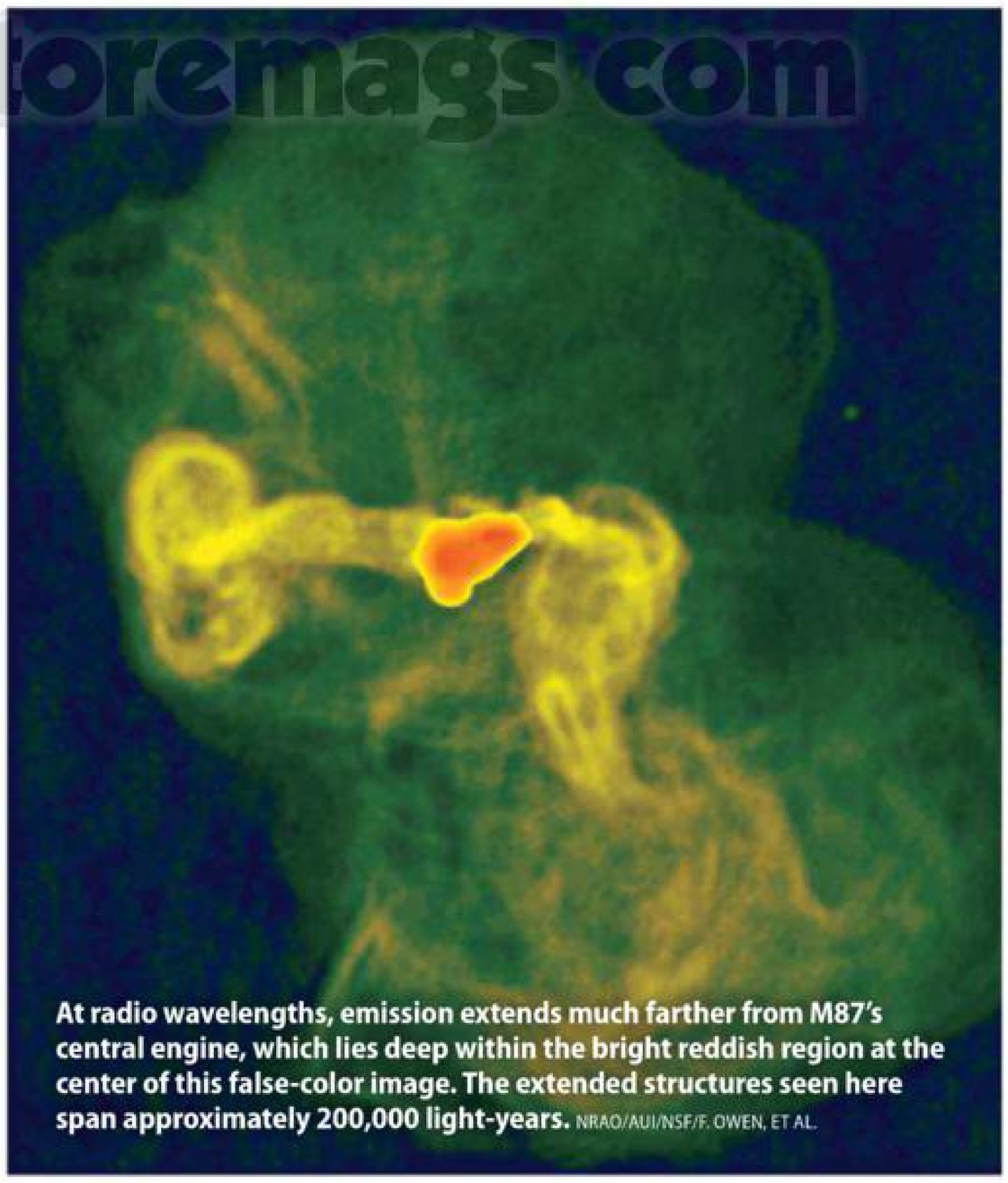
Hot shocks and bubbles

The AGN engine would have to be incredibly efficient to pull off such a feat. With the benefit of Chandra's observations and with contributions from many colleagues, Forman, Jones, and Churazov identified the two main ways in which M87's black hole heats the gas: bubbles and shock waves. This confirmed the general picture that earlier observations and theoretical efforts had been hinting at. In fact, Churazov had proposed as far back as 2000, before he had access to Chandra data, that bubbles and "shocks" would be the most important heating mechanisms.

This is the basic scenario: The process starts when the supermassive black

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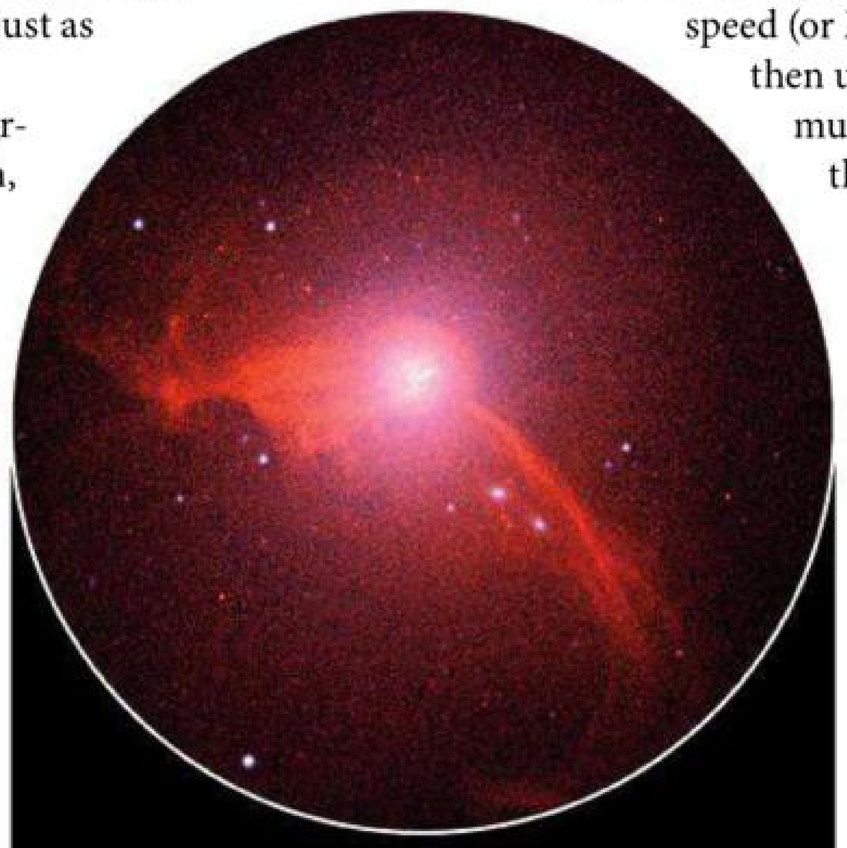
At radio wavelengths, emission extends much farther from M87's central engine, which lies deep within the bright reddish region at the center of this false-color image. The extended structures seen here span approximately 200,000 light-years. NRAO/AUI/NSF/F. OWEN, ET AL.

hole shoots out two jets in opposite directions moving at close to light-speed. Each jet drives away the hot gas that envelops the black hole, carving out a cavity, or bubble, of fast-moving plasma and magnetic fields — the stuff that makes up the jet — in the gas.

Because the bubbles have a lower density than their surroundings, buoyancy causes them to rise. As they ascend, they enter a more rarefied environment and expand, flattening into pancake shapes. The soaring bubbles transfer the black hole's energy, which initially carved out the cavities, to the gas that they shove aside. As the bubbles continue to rise, the gas flows around them and gains kinetic energy that later gets converted to heat. The gas grows hot simply by being forced to move, just as water heats up when you stir it.

"But that's just half of the story," says Forman. "If you blow up [a] bubble fast enough, you'll push the outside gas so hard that you create a shock wave." Such shock waves then rip through the surrounding atmosphere at high velocity — at or above the speed of sound in the medium — while the bubble trails behind at a much slower pace.

The shock waves heat the gas as they pass through, losing energy as they go. The shocks show up in X-rays where the surface brightness changes sharply, says Forman. Thanks to Chandra, the researchers saw this in M87 more clearly than previous observations had revealed elsewhere. M87's shock waves appear as a nearly circular ring of higher-pressure gas moving out from the black hole at a distance of about 42,000 light-years.



This composite image of M87 shows relatively low-energy X-rays as red and visible light from stars as blue. Outbursts near the central supermassive black hole occur roughly every 10 million years and produce the unevenly spaced loops and bubbles in the X-ray gas. X-RAY: NASA/CXC/CfA/W. FORMAN, ET AL.; OPTICAL: DSS

A long-lived outburst

Through a detailed analysis of the shock waves spotted around M87, the team estimated how long the black hole had been in outburst mode. The scientists first measured the temperature and density in the black hole's vicinity. They then used a formula developed in the 1800s by Scottish physicist and engineer William Rankine and French engineer Pierre Hugoniot. The Rankine-Hugoniot equation allowed the team to determine the strength of M87's shock waves.

Based on the shock waves' power and the speed at which they propagate — "Mach 1.2," or 1.2 times the speed of sound — the astrophysicists worked backward and concluded that the outburst had originated more than 10 million years ago. They also calculated that it lasted 2 million years, which is how long it took the jets to inflate the bubble. "It wasn't a particularly violent outburst," Forman observes, noting that if the bubble had inflated faster, it would have led to a much stronger shock wave.

The team reached this conclusion by combining radio and X-ray observations. Frazer Owen of the National Radio Astronomy Observatory and his colleagues targeted M87 with the VLA in 2000 while Forman, Jones, Churazov, and others collected Chandra data during the ensuing decade. "This is the first time people were able to measure the duration of a black hole outburst," says Jones. "It's taken a lot of work to get this result."

Meanwhile, there's a new outburst going on in M87, she adds, with a new bubble expanding as we speak: "It appears that a whole series of bubbles are being formed — and outbursts being set off — roughly once every 10 million years."

The power of the outbursts, moreover, appears roughly the same as the rate at which the cluster gas radiates energy. But Forman and company wanted to carry their analysis even further. They homed in on the relative contributions of the bubbles and shocks to heating the gas.

To work out the bubble component, the researchers started by mapping the density and temperature of the gas, which allowed them to derive the pressure. Then, knowing the bubble's volume and the surrounding pressure, they computed the energy it took to inflate the bubble — energy that eventually heats the gas.

As for the shock component, the astrophysicists applied the Rankine-Hugoniot equation to determine the relative speed (or Mach number) of the shock waves. They then used this Mach number to calculate how much energy the shock waves deposited into the surroundings as they passed through.

Based on observations of M87 and other galaxies, astronomers now know how much energy the jets transfer from a black hole's outburst to the gas. The bubbles transmit roughly half of the jets' energy to the gas around the black hole while the shock waves account for about one quarter. The remaining quarter is lost — dissipated at the outskirts of the cluster by weak shock waves that don't heat the gas much.

Bringing balance to the force

One of Forman's team's more remarkable findings is that the M87 system appears to stay within a fairly tight balance. "It looks like enough energy comes from the



A black hole with roughly 6 billion times the Sun's mass lurks at the center of M87. In this artist's concept, gas and dust circle the black hole in a so-called accretion disk. As the black hole's gravity pulls in this material, magnetic fields channel some of it into a high-speed jet that emerges perpendicular to the disk.
NASA/JPL-CALTECH

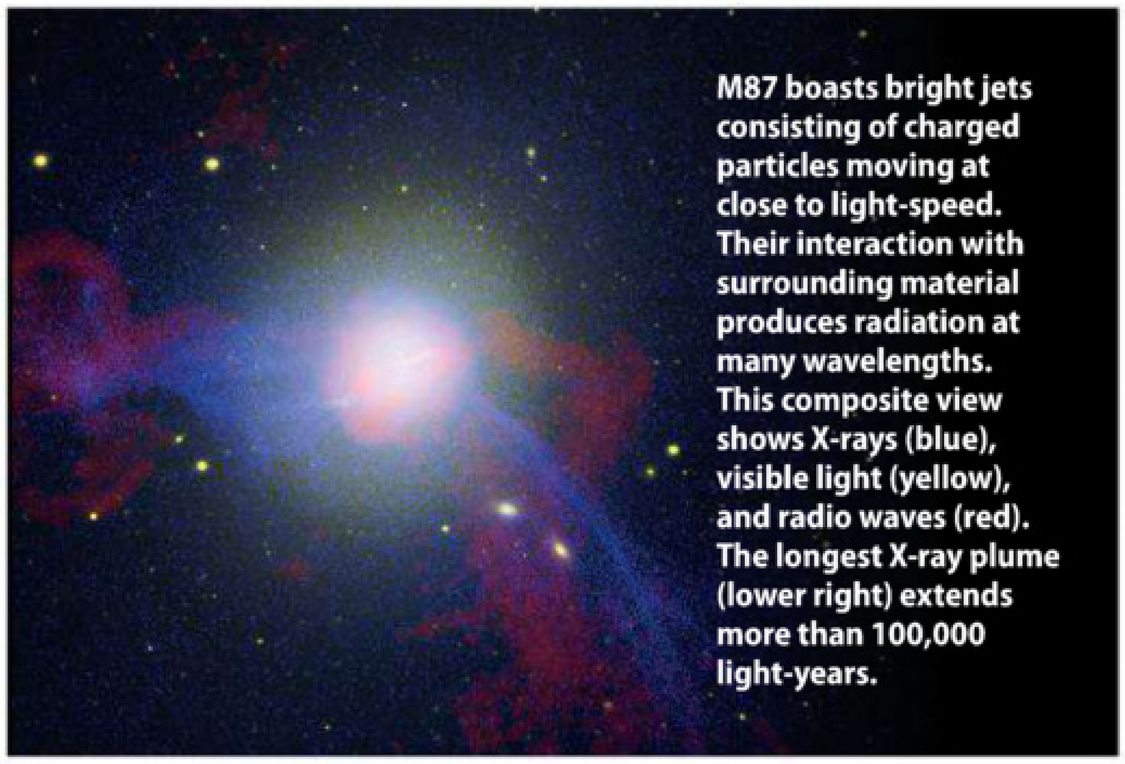
black hole to keep things steady over billions of years," says Forman, "[but] nobody knows exactly how this self-regulation works."

"Somehow the AGN has to decide how much energy to put into the outlying medium," explains Churazov. "To do that, there has to be some kind of feedback loop." The AGN heats the gas while the gas provides matter to the black hole, so they maintain a kind of equilibrium. If the AGN puts too little heat into the atmosphere, the gas cools and gets denser. This causes more gas to accrete onto the black hole, which then pumps more energy into the gas, thereby reducing the amount of cooling gas and quelling the outburst.

"The AGN keeps the gas at a relatively constant temperature and density, just as the thermostat on an air conditioner keeps a room at a fairly steady temperature," says Churazov. The regulation in M87 is by no means exact, though. Unlike an air conditioner, which typically lags a few minutes, M87 likely takes a few million years to regulate itself. "There may be a little accretion onto the black hole followed by an explosion that delays the next episode of gas cooling," he says. "But there's no guarantee that at every instant the energy loss and energy release are perfectly matched."

Because of M87's proximity, and the fact that its temperature places it in the "sweet spot" for Chandra's instruments, astronomers have gleaned details — such as measuring the shock wave fronts and their associated velocities — that they have not yet been able to see in other galaxy clusters. "M87 is the rare case where you can compute just about everything," says Forman. That said, M87 appears typical, both of large galaxies at the centers of clusters and of large active galaxies that do not lie in a cluster's core. So far, X-ray studies have revealed at least 50 examples of galaxies and clusters with bubbles and cavities.

"The major breakthrough came when Chandra started to show the same thing occurring in many, many galaxies and clusters over a wide range of scales," says Churazov. In dozens of galaxies smaller than M87, such as M84 and NGC 5813, and clusters larger than Virgo, including the Perseus and Hydra clusters, the supermassive black holes appear to regulate themselves. Each provides just the right amount of energy to keep things relatively stable. It's a remarkable discovery given that these giant black holes are capable of unleashing incredible havoc yet seem to behave in such a restrained and seemingly responsible fashion.



M87 boasts bright jets consisting of charged particles moving at close to light-speed. Their interaction with surrounding material produces radiation at many wavelengths. This composite view shows X-rays (blue), visible light (yellow), and radio waves (red). The longest X-ray plume (lower right) extends more than 100,000 light-years.
X-RAY: NASA/CXC/CfA/W. FORMAN, ET AL.; RADIO: NRAO/AUI/NSF/W. COTTON; OPTICAL: NASA/ESA/THE HUBBLE HERITAGE TEAM (STScI/AURA) AND R. GENDLER

A wealth of discoveries has emerged since NASA launched Chandra in 1999 and the observatory began probing the X-ray sky. In that time, astronomers have unraveled many mysteries concerning M87 and other players in its high-energy realm. If astronomers didn't have X-ray and radio observations, and instead were limited to optical astronomy, humans would be largely in the dark about these objects, says Forman: "We would have missed this whole exciting story about black holes and jets, and bubbles and shocks, because the stars themselves play little role in this violent drama."

TO SEE A VIDEO ZOOMING IN ON THE JET EMANATING FROM M87'S CORE, VISIT **www.Astronomy.com/toc.**

Live fast, die young

Secret lives of supermassive stars

The Tarantula Nebula in the Large Magellanic Cloud holds hundreds of thousands of young stars. The star formation region at lower center, 30 Doradus, harbors the super star cluster R136, which contains the most massive star known. NASA/ESA/E. SABBI/STScI

ive stars

The most massive stars burn through their material incredibly fast, die in fantastic explosions, and have long-lasting effects on their neighborhoods. **by Yvette Cendes**

Supermassive stars are the true rock stars of the universe: They shine bright, live fast, and die young. Defined as stars with masses a hundred times or more than that of our Sun, these stars can be millions of times more luminous than ours and burn through their fuel supplies several thousand times faster.

If you have a hundred times more money than your neighbor but spend it several thousand times faster, you will go bankrupt more quickly — the same happens for stars. While our Sun's lifetime is about 10 billion years, a supermassive star dies in just a few million years in an explosion that astronomers can detect more than halfway across the visible universe. These stars lead unusual lives, from beginning to end.

In our galaxy of 200 billion stars, perhaps just a few dozen of these supermassive luminaries exist. Despite their rarity, which makes them difficult to study, these stars are a popular research focus because their formation, lives, and deaths greatly impact how other suns form and evolve. Studies of these luminaries also yield clues about the first stars in the early universe.

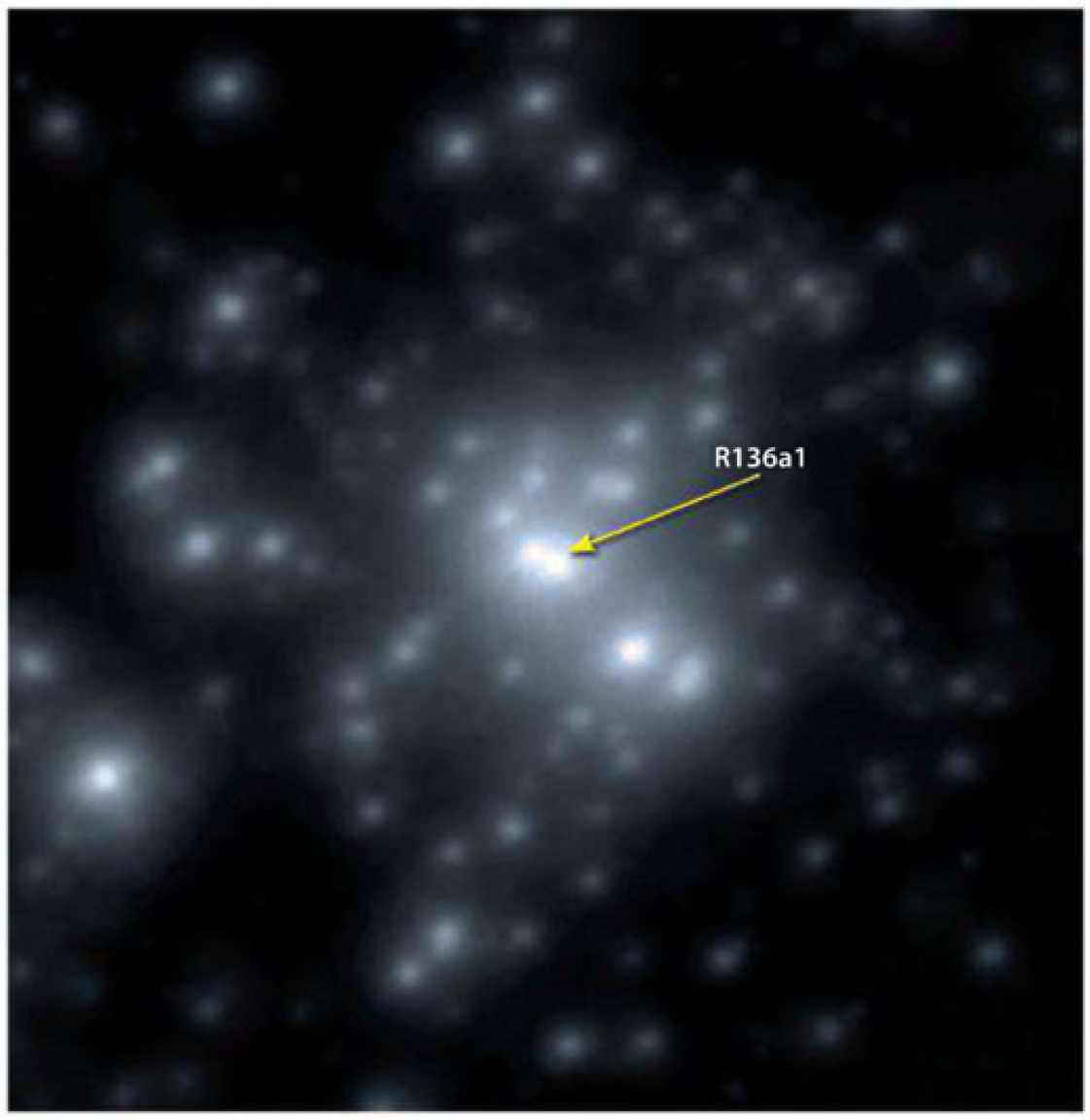
Into the light

Astronomers think that supermassive stars likely begin forming similar to almost all their smaller siblings: in dense clouds of gas and dust called nebulae. Some outside source — like an incoming shock wave — probably causes turbulence, which makes the cloud's material begin to assemble. This new clump attracts more and more gas and dust until it begins to collapse under its own weight to form an object known as a protostar. In the process, its gravitational energy converts to kinetic energy, which heats the protostar. The object spins as material collapses inward due to the conservation of momentum, and more gas and dust fall into the protostar until it is dense and hot enough for hydrogen nuclei to fuse into helium nuclei. This nuclear fusion at its core will drive the star through most of its life, until it runs out of material millions, billions, or even trillions of years later.

One crucial difference exists in the formation process, though: The larger the star, the more quickly it grows during these initial stages, and thus the faster hydrogen fusion begins at its core. A star the size of our Sun takes an estimated 50 million years to form; a supermassive star that begins its life a hundred times larger will take only tens or hundreds of thousands of years to develop. Most stars grow in clusters embedded in nebulae and thus have several neighbors, so these very massive stars can influence stellar growth around them.

Yet the formation process of these suns still holds many puzzles for astronomers. To verify star formation theories, scientists compare computer models with observations. When they simulate a spinning protostar accreting such a large mass, it often falls apart into several pieces instead of growing into one supermassive star. Because of this, astronomers debate exactly how the largest stars are created. "In the last 10 years, the debate has centered on whether these stars were

Yvette Cendes *is a doctoral student in radio astronomy at the University of Amsterdam. Her Twitter handle is @whereisyvette.*



R136a1, clocking in at 265 solar masses, lies at the center of this image. Astronomers have determined it was even larger when born 1.5 million years ago: more than 300 solar masses. A powerful stellar wind has contributed to its weight loss since birth. ESO/P. CROWTHER/C. J. EVANS

created in one large disk accreting or competitive accretion with multiple clumps merging together to produce them," explains Paul Crowther of the University of Sheffield in the United Kingdom. The star clusters where supermassive stars form are especially dense and chaotic places, and the more massive members of a stellar cluster tend to appear toward its center. As a result, a supermassive star could be the outcome of several stars crashing into each other. Astronomers aren't yet sure which formation process nature follows or if both contribute to these mammoth stars.

Popular neighborhoods

While scientists may not know exactly how extremely massive suns form, they certainly know the stars exist. The most famous example, Eta Carinae, is a star visible to the unaided eye in the Southern Hemisphere. This binary system lies about 7,500 light-years from Earth and has a primary star with a whopping 100-some solar masses.

But stars can be even larger: In 2010, Crowther led a team that found R136a1, the most massive known star in the universe at 265 solar masses. This sun is part of the R136 cluster, which boasts several other massive stars. It lies in the 30 Doradus star cluster, which sits in the Tarantula Nebula (NGC 2070) in the Large Magellanic Cloud, a dwarf galaxy that's a satellite of the Milky Way. This nebula is the most active starburst region in our galaxy's local neighborhood; a famous stellar explosion in 1987 occurred near its edge. Astronomers now know that the progenitor of Supernova 1987A, as the event was cataloged, was about 20 solar masses before its energetic death. "We are very lucky 30 Doradus is right next door," explains Frank Tramper of the University of Amsterdam in the Netherlands, because it allows the team he works with to conduct what he calls "fishing expeditions" to find supermassive stars in the region using the Very Large Telescope in Chile.

But 30 Doradus holds thousands of stars, so in order to find and weigh the largest cluster members, astronomers must resort to several tricks. One of the most used methods requires them to first measure a star's brightness at different wavelengths to determine its intrinsic luminosity. They then utilize a relationship between a star's luminosity and its mass — an analysis that can carry high uncertainty because measuring an individual star's precise brightness can push the limits of current technology. Astronomers also rely on supermassive suns in binary star systems to calibrate these luminosity measurements by using the stars' orbits around each other and the laws of motion developed by German astronomer Johannes Kepler (which are also at work in our solar system). Luckily, and for reasons not entirely clear, scientists find most supermassive stars in multiple-star systems, so they can use this technique often.

Today, astronomers are discovering more and more of these objects to study. In early 2013, a team announced that the most massive known binary star, R144, has a combined mass between 200 and 300 times that of the Sun. The curious thing about R144 is that it lies in the outer regions of 30 Doradus. Current theories about supermassive star formation — driven not just by observations but by computer simulations of how these stars form — dictate that the system should have formed toward the more hydrogen-rich center of the nebula. In fact, astronomers have not yet successfully modeled a binary forming in isolation. Further complicating matters, no one has observed a supermassive binary in its creation stages. Either the current theories are wrong about supermassive binary formation, or R144 interacted with other stars often enough to be flung rapidly from the cluster's dense center.



In the early 19th century, Eta Carinae's (center) brightness varied significantly, peaking at roughly magnitude –1 in 1843. That event threw off an estimated 10 solar masses of material, which now takes on a dumbbell shape known as the Homunculus Nebula. ESA/HUBBLE & NASA

Where the wind blows

Regardless of the details, astronomers do know that after a supermassive star forms, it leads a brief but volatile life. Such a sun has strong stellar winds that create powerful outflows of material from its outer layers. "Unlike humans, these stars are born heavy and lose weight as they age," explains Crowther. "R136a1 has an estimated age of around 1.5 million years and has already lost an estimated 20 percent of its mass, or more than 50 solar masses." This means that even though it is the most massive star known today, R136a1 would have been more than 300 times the Sun's mass when it formed and might weigh as little as 100 solar masses at the end of its life in another 1–2 million years.

EARTH IN THE CROSSHAIRS?

Astronomers debate if supermassive binary Eta Carinae will release a gamma-ray burst (GRB, the most energetic type of blast in the cosmos) when it dies and whether such a GRB would impact life on Earth due to how close the system is to us — about 7,500 light-years. Such a burst, if it occurred, would not directly affect Earth's surface, but it would impact satellites and any astronauts in orbit. It also could severely deplete the ozone layer, which could lead to an extinction-level event. But don't get too worried: Eta Carinae's rotation axis is not aligned with Earth, so if the star generates a GRB, it is very unlikely to hit us. — *Y. C.*

VISUALIZATION: RALF KÄHLER, TOM ABEL; SIMULATION: JOHN WISE, TOM ABEL



The first stars in the universe, like that shown in this computer simulation, were likely objects with at least 100 solar masses. They burned through their primordial hydrogen and helium quickly and produced many heavier elements that they then spewed into space during their explosive deaths.

Volatile winds also make massive stars unpredictable and prone to outbursts. Eta Carinae has undergone such flare-ups in the past: While it currently shines at about 5th magnitude, in the mid-19th century astronomers recorded a surge where the star reached nearly magnitude –1 — making it the second-brightest star in the night sky after Sirius despite being several thousand light-years farther from Earth. It remained that bright for years and eventually dimmed to 8th magnitude by the end of the century. Since the 1940s, Eta Carinae has been slowly brightening to reach its current magnitude. Astronomers are still not sure what exactly triggered the "Great Eruption," but they estimate the binary star shed about 10 stellar masses during this outburst; the material is still visible as the Homunculus Nebula that surrounds the system. Scientists think the binary star will experience more violent outbursts on its way to exploding as a supernova.

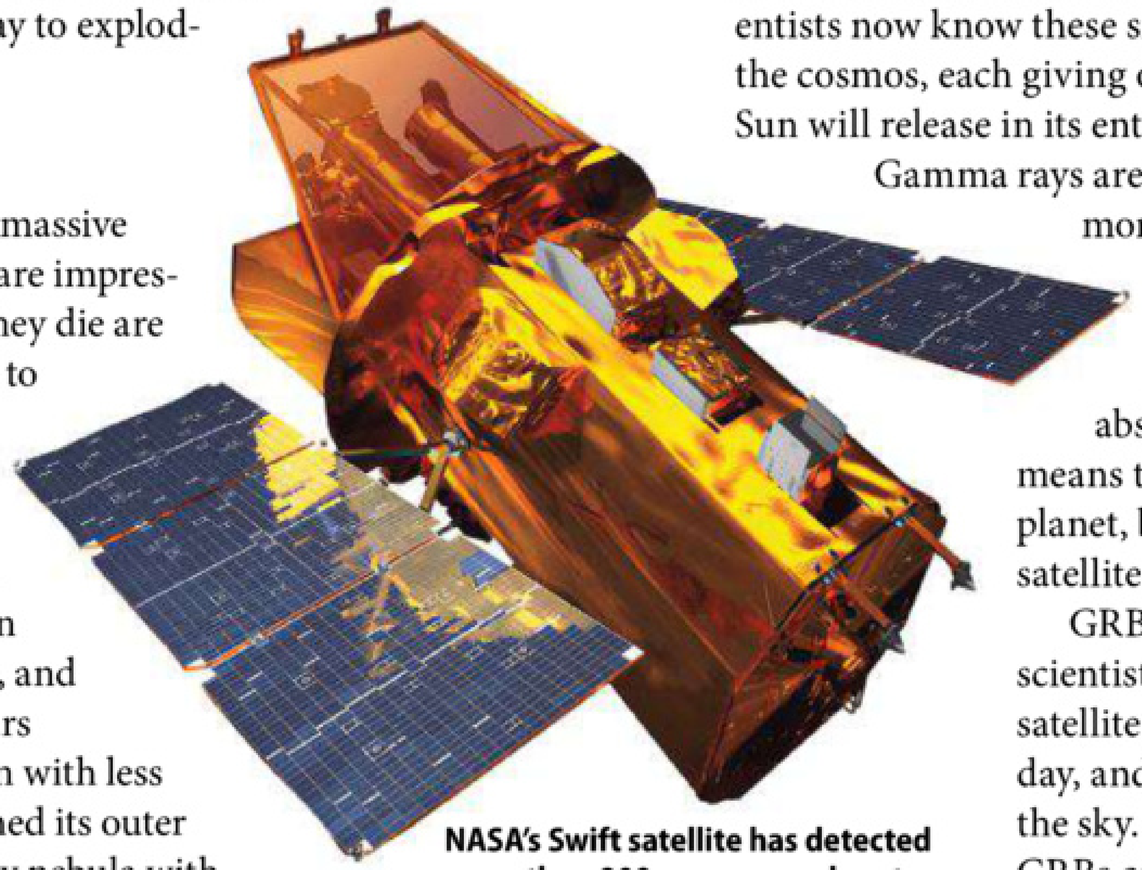
With a bang

While the outbursts supermassive stars can have while alive are impressive, the outbursts when they die are truly spectacular. The key to the fabulous flare-ups is that every star eventually runs out of fuel to control the nuclear fusion processes in its core. When this happens, the star dies, and the sort of death that occurs depends on its mass. A sun with less than 8 solar masses will shed its outer layers and leave a planetary nebula with its dense remnant core, now called a white dwarf, in the middle; a star larger than that usually will explode in a supernova that can shine brighter than all the other suns in a galaxy combined. But not all supernovae are equal: A star with less than some 20 solar masses will leave behind a dense neutron-star core while a more massive one will collapse and create a black hole.

The formation of a black hole is a violent event — so violent that it can release a light signature seen across most of the visible universe. The blast that signals this catastrophic death was discovered by accident during the height of the Cold War. The U.S. military launched a series of satellites, known as the Vela project, to detect gamma-ray flashes in case the Soviets violated the 1963 Nuclear Test Ban Treaty. The Vela project never confirmed any atmospheric nuclear explosions, but it did detect gamma-ray flashes coming from above Earth — mysterious bursts from space that had unknown origins. These flashes, which the military declassified in 1973, were the first detected gamma-ray bursts (GRBs). Scientists now know these signals are the most powerful explosions in the cosmos, each giving off more energy in a few seconds than the Sun will release in its entire lifetime.

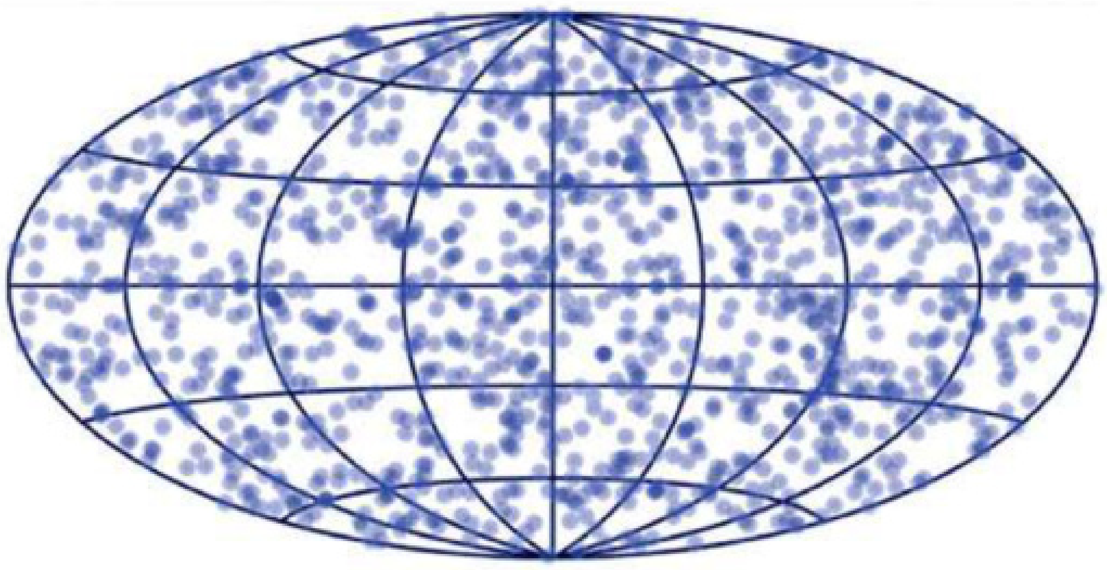
Gamma rays are the part of the electromagnetic spectrum more energetic than X-rays, and just one gamma-ray photon can pack thousands of times more energy than a visible-light photon. (Earth's atmosphere thankfully absorbs gamma rays, like X-rays, which means these flashes do not affect life on our planet, but it does mean astronomers must launch satellites to detect them.)

GRB astronomy has come a long way since scientists initially found these blasts. NASA's Swift satellite now detects approximately one GRB a day, and the bursts originate from all directions in the sky. Astronomers also have determined that GRBs come in three types: short-duration bursts that last just milliseconds, long-duration ones that last minutes, and ultralong-duration bursts that can last hours. They know that the latter two types result from the death of a massive star, while



NASA's Swift satellite has detected more than 900 gamma-ray bursts (GRBs). As soon as it senses a blast, it slews to observe it and also sends the GRB's coordinates to a network of other telescopes. NASA E-PO/SONOMA STATE UNIVERSITY/AURORE SIMONNET

GRBs occur everywhere



Astronomers find gamma-ray bursts all over the sky. Some of these blasts result from the high-energy deaths of rare supermassive stars. THE GAMMA-RAY BURST REAL-TIME SKY MAP (SONOMA STATE UNIVERSITY)

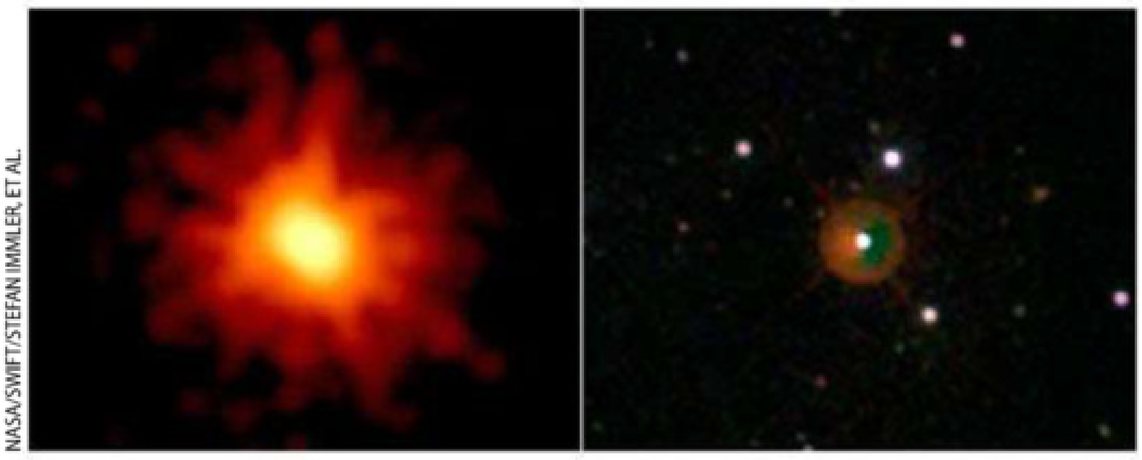
short-duration GRBs come from the violent merger of two neutron stars or a neutron star and a black hole.

When Swift, or another telescope, detects a GRB flash, astronomers receive that object's coordinates within minutes via text message and a network of instruments around the globe slews to view the object. A GRB's emission also rams into nearby material, which causes that material to glow in less energetic radiation. By studying these GRB afterglows in different wavelengths, astronomers have learned that the brightest and longest GRBs come from galaxies rich in star formation and that often a new, bright supernova will appear in the same location on the sky as a GRB. A supernova signals the death of a star, so this correspondence implies that the deaths of the most massive stars trigger some of the most violent and energetic phenomena in the universe; astronomers have a name for such an incident — a collapsar or hypernova.

As the core of a star collapses into a black hole, the remaining stellar material falls toward the center and swirls into a high-density accretion disk surrounding the stellar remnant. Through complex mechanisms not yet understood, matter from this accretion disk will be swept into jets of material at the poles of the star, and when the jets reach the star's surface, they will release gamma-ray energy in the direction of the jets. If one of these jets is aimed directly at Earth, telescopes see a long- or ultralong-duration GRB.

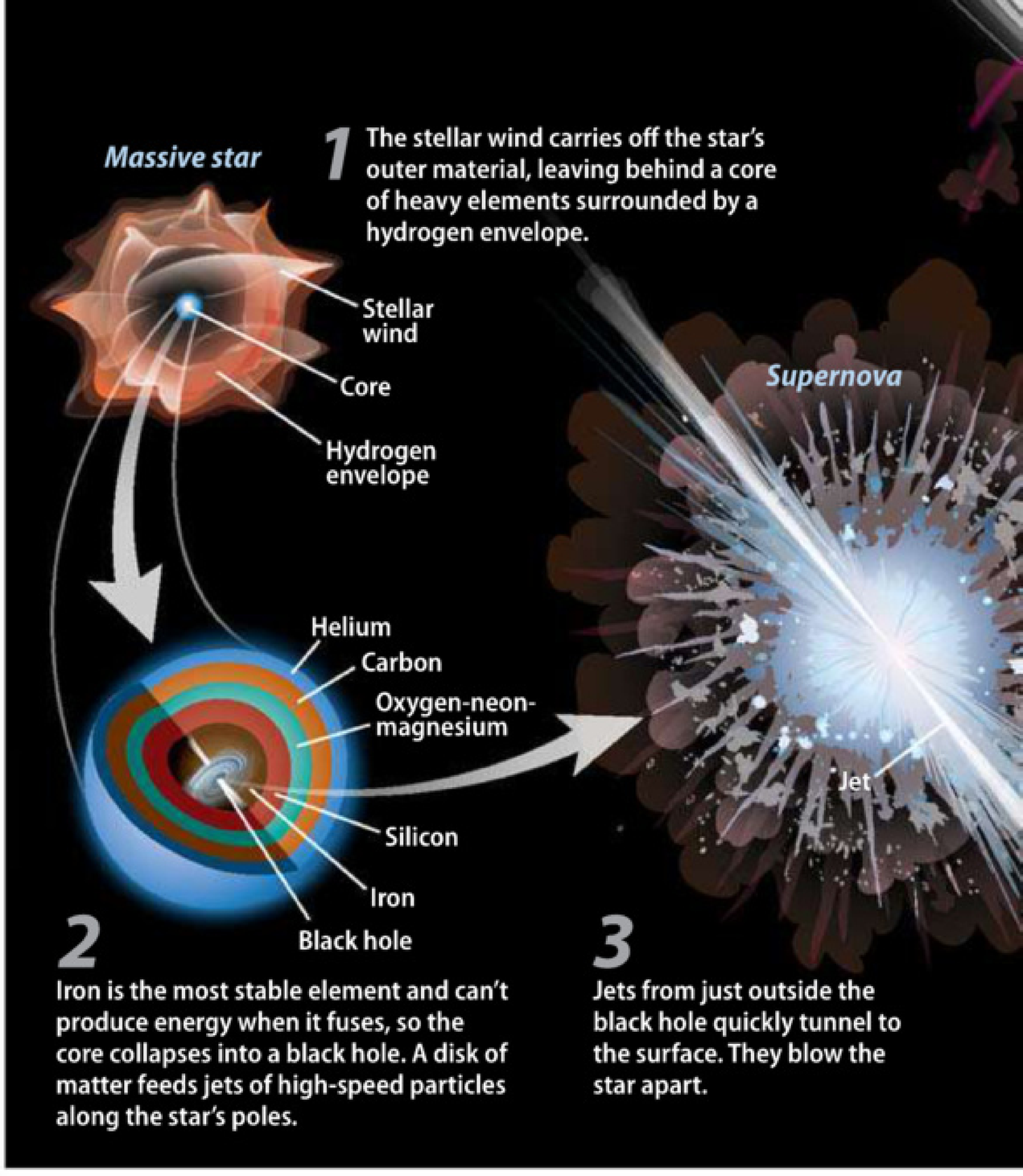
Record breakers

GRBs are rare — a galaxy the size of the Milky Way will have only a handful every million years or so. To find more of them, astronomers must look far from our galaxy. The more distant an object is from Earth, the longer the light has been traveling to reach us and thus the further back in time that object existed. One GRB holds



NASA/SWIFT/STEFAN IMMLER, ET AL.

On March 19, 2008, NASA's Swift satellite detected the gamma-ray burst (GRB) from a massive star's explosion. The blast was so bright that anyone at a dark site and looking at the constellation Boötes could have seen it. This image shows the observed X-ray afterglow from Swift (left) and the GRB's optical afterglow.



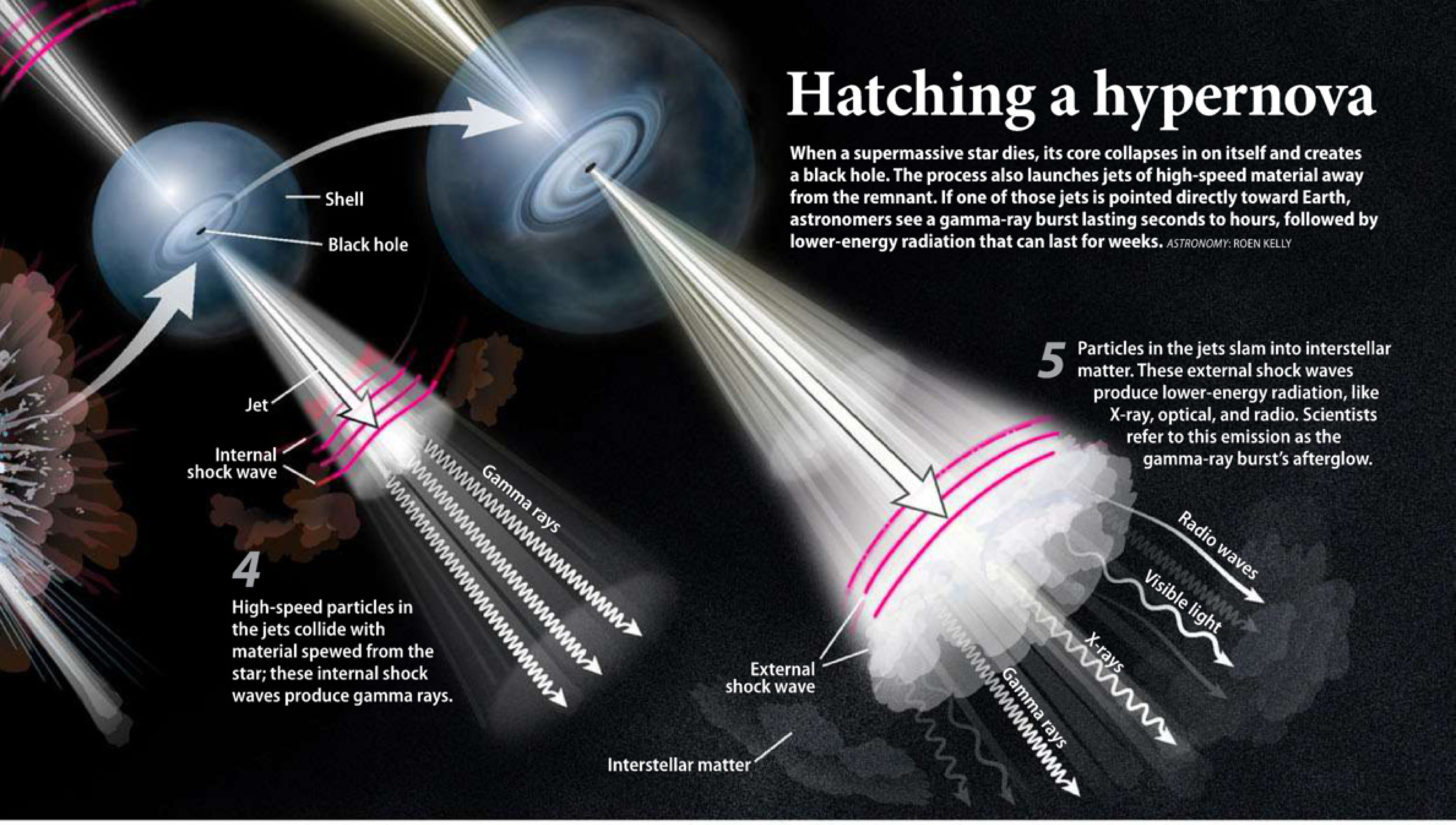
the record for the farthest object seen with the unaided eye: On March 19, 2008, the beam from GRB 080319B was so powerful that its afterglow reached a visual magnitude of 5.3 for approximately 30 seconds. Anyone who happened to be looking at the right spot in the constellation Boötes at the time under dark skies would have seen the glow of a star dying 7.5 billion years ago.

But that's not the only GRB that holds a record: The most distant object that astronomers have directly detected was a GRB that exploded a mind-boggling 13.2 billion years ago, and its light just arrived at Earth in 2009. The supernova that spawned this blast occurred just 620 million years after the Big Bang, when the first galaxies were beginning to form.

Those two GRBs are long-duration types. In recent years, astronomers also have detected ultralong-duration GRBs that appear to come specifically from supermassive stars. Astronomers detect the gamma-ray signal from these objects for hours instead of several minutes. They believe that these ultralong bursts result from the same mechanisms that create long GRBs — that is, jets from a star collapsing into a black hole — except the star is especially wide and massive. This process could happen for a massive or supermassive star that does not have powerful winds that spew its outer layers over time, so such a star holds onto its gas and has a radius as large as Jupiter's orbit. Because the edge of this sun is so much farther out than a star that has shed much of its material, it takes longer for the explosion to propagate through the star. The black hole also has more material to feed on, powering an ultralong-duration GRB.

The earliest rock stars

Such GRB glimpses are intriguing to astronomers who want to learn about the first generation of stars in the universe, called Population III. The chemical composition of the cosmos was different in the first few hundred million years, and thus so were the stars that were born from that material. The universe held the basic elements that formed just minutes after the Big Bang — roughly

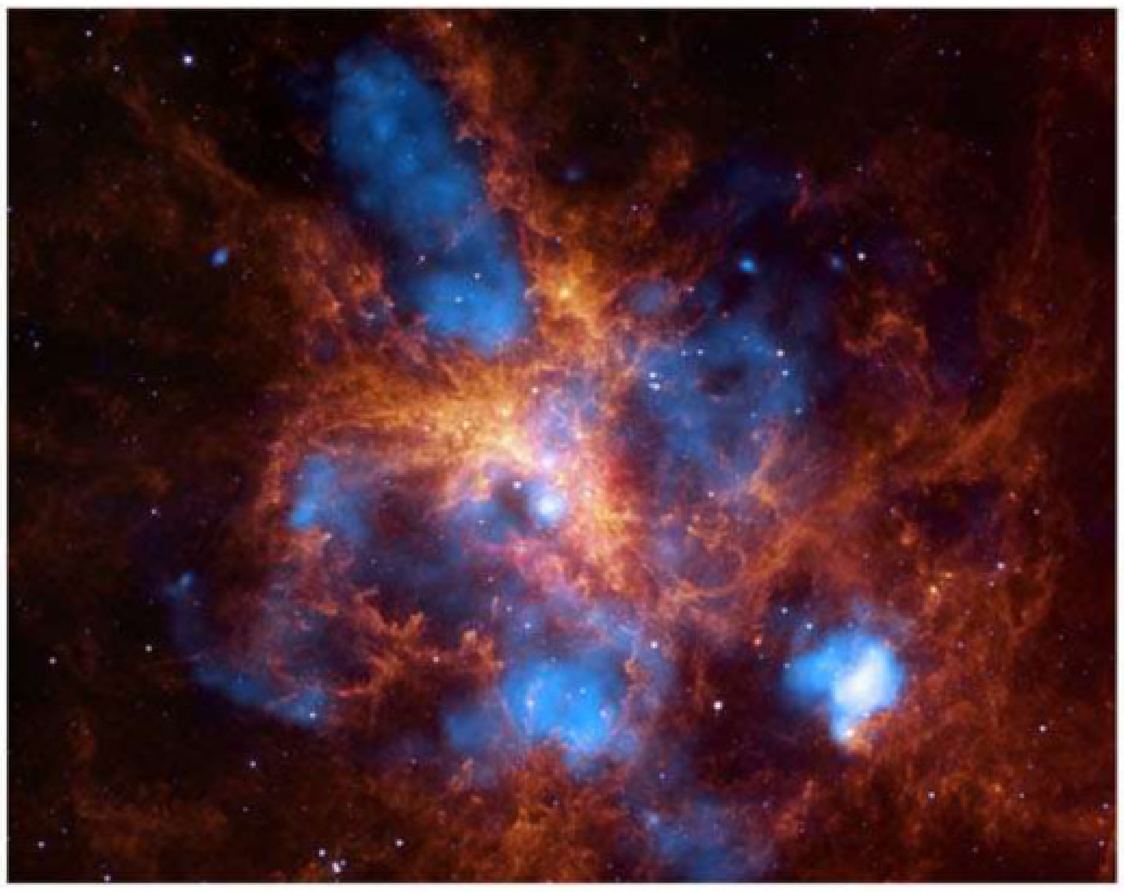


75 percent hydrogen, 25 percent helium, and a few trace "metals." (Due to their rarity compared to hydrogen and helium, all elements above helium in the periodic table are metals according to astronomers.) Metals are more efficient at cooling a dust cloud than pure hydrogen, and at cooler temperatures, smaller stars form. In a metal-free environment, however, the dust cloud will be warmer, and computer simulations show stars that form in such environments will be much more massive than those seen today, growing to a few hundred solar masses.

No one is quite certain exactly how big these first stars were because astronomers don't yet have the capability to observe them directly; so far they have only hints of these suns in stray light lensed by the intense gravity of intervening galaxies. Astronomers hope NASA's upcoming James Webb Space Telescope will provide the first glimpses of Population III stars.

Scientists estimate that these first stars, due to their truly supermassive size, would have lived just a million years before exploding as brilliant supernovae. But before these blasts occurred, these stars would have fused in their cores the first 26 elements on the periodic table, including carbon, oxygen, silicon, and iron. Population III stars left their mark as the first suns to inject metals into the universe, but in this way they also doomed themselves: They spread these elements so effectively throughout the cosmos that astronomers do not see any metal-free stars today.

The brief but brilliant lives and deaths of supermassive stars have played, and continue to play, a huge role in star formation around them. "They are the motors of the galaxy because when they explode as supernovas, they dynamically and chemically enhance their surroundings," explains Lucas Ellerbroek of the University of Amsterdam. "They put a lot of extra metals into their environment, and although it's never been proven, it's thought the supernovas trigger other waves of star formation."



X-RAY: NASA/CXC/PSU/L. TOWNSLEY, ET AL.; INFRARED: NASA/JPL/PSU/L. TOWNSLEY, ET AL.

The massive stars in 30 Doradus shed material and radiation, which then plow into nearby gas. These collisions heat the gas to millions of degrees, which emits X-rays, shown as blue in this composite image.

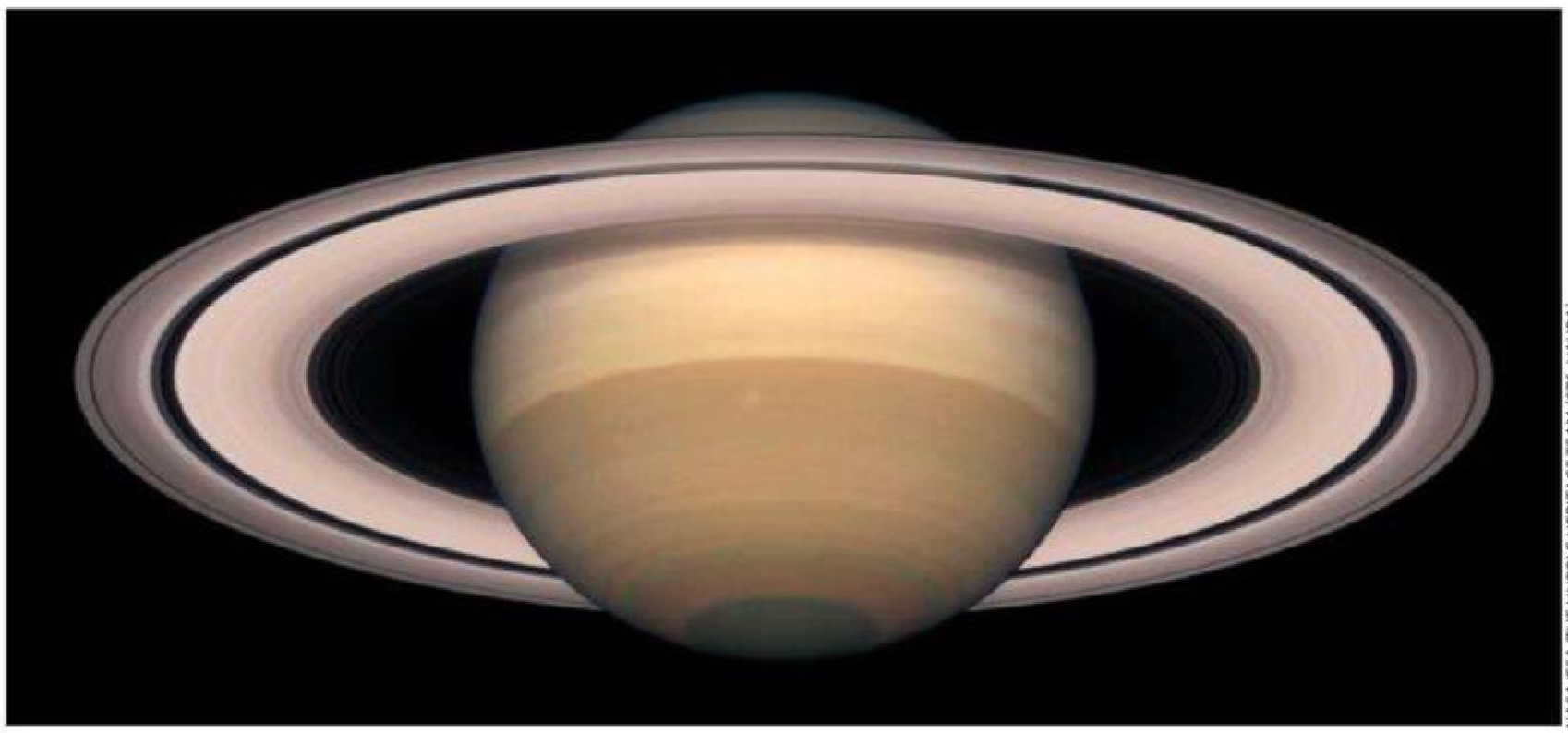
Such stars also have affected us directly. It is possible that in whatever long-forgotten nebula our Sun formed, the material initially clumped because of the life and death of a nearby supermassive star. More tangibly, virtually every element on Earth was fused in a star's core long ago — from the carbon in your body to the oxygen you breathe and the silicon in your computer — in a chain of events that stretches back to the first stars in the universe. Supermassive stars are rare, but they are crucial to the universe's evolution and have played a key role in shaping both our lives and those of stars and galaxies across the cosmos.

WATCH A COMPUTER SIMULATION OF THE FIRST STAR'S EVOLUTION AT **www.Astronomy.com/toc.**

MARTIN RATCLIFFE and **ALISTER LING** describe the solar system's changing landscape as it appears in Earth's sky.

Visible to the naked eye
Visible with binoculars
Visible with a telescope

MAY 2014: Saturn's majestic opposition



NASA/ESA/THE HUBBLE HERITAGE TEAM (STScI/AURA)

Saturn's rings open wider this year than at any time since 2005, offering observers great views through any telescope.

Three planets provide a stunning variety of viewing options this spring. Do you like tracking atmospheric features? Jupiter offers plenty of opportunities in early evening. Do you prefer seeing planetary surfaces? Mars, now just one month past its best, continues an eye-catching show nearly all night. Or perhaps gorgeous ring systems excite you most? Then don't miss Saturn, which reaches opposition and peak visibility in May, with its rings open wider than at any time since 2005. Add Mercury glowing bright in evening twilight and Venus dominating before dawn, and May's smorgasbord rivals any this year.

Let's begin our tour with the vista that awaits on May's first evening. The Pleiades and Hyades star clusters in Taurus the Bull hang low in the west as twilight fades to darkness. To their left, you'll spot Orion the Hunter's familiar form starting to slip below the horizon. Continue scanning to the left, and you can't miss the sky's brightest star, Sirius, probably twinkling like crazy as its light passes through thick layers of air near the horizon.

Above the Hyades stands a smiling crescent Moon, with just 8 percent of its visible surface lit. Crane your neck higher, and you'll spot Jupiter's brilliant orb nearly halfway from the western horizon to the zenith. The giant planet glows near the center of Gemini the Twins, just below that constellation's brightest stars, Castor and Pollux.

Mercury joins the evening scene at the end of May's first week when it passes 3° south of the Pleiades. The innermost planet shines at magnitude –1.1, far brighter than the star cluster. Use binoculars for the best view. By May 13, Mercury has dimmed to magnitude –0.6 as it slides 8° north of 1st-magnitude Aldebaran, Taurus' brightest star.

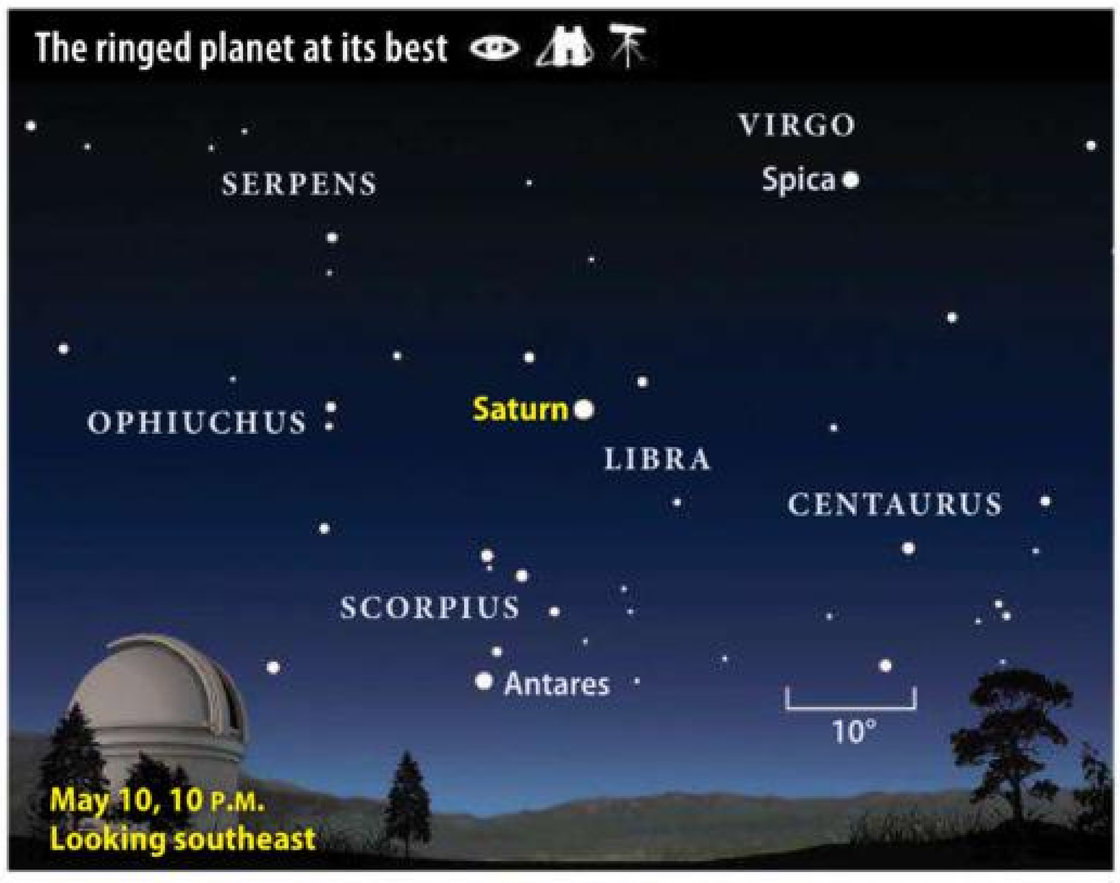
The inner world reaches its peak May 24 when it lies 23° east of the Sun, the maximum elongation for this evening appearance. Although Mercury has faded to magnitude 0.4, it sets a full two hours after our star.

While Mercury is bright, **Jupiter** is dazzling. The giant planet shines at magnitude –2.0 May 1 and fades by just 0.2 magnitude during the month, values that beat every other planet and star in the evening sky. And Jupiter remains on display for hours, setting near midnight local daylight time in mid-May.

For the best views of Jupiter through a telescope, start observing within an hour after sunset. Its greater altitude in early evening will deliver sharper views of atmospheric features.

The planet's disk spans an impressive 34" at midmonth. This is big enough that even small telescopes will show two dark equatorial belts sandwiched around a brighter equatorial zone. Larger apertures reveal more belts and zones as well as details within these cloud bands. The Great Red Spot — a fairly strong shade of orange earlier this year — also should show up nicely when it is on the Earth-facing hemisphere.

Jupiter's four bright moons present an ever-changing display. Although it's worth



Saturn reaches opposition and peak visibility May 10, when it shines brightly in the southeast after darkness falls. *ASTRONOMY:* ROEN KELLY

Martin Ratcliffe *provides planetarium development for Sky-Skan, Inc., from his home in Wichita, Kansas. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

storemags

RISING**MOON**

A frigid sea beckons in Luna's northeast

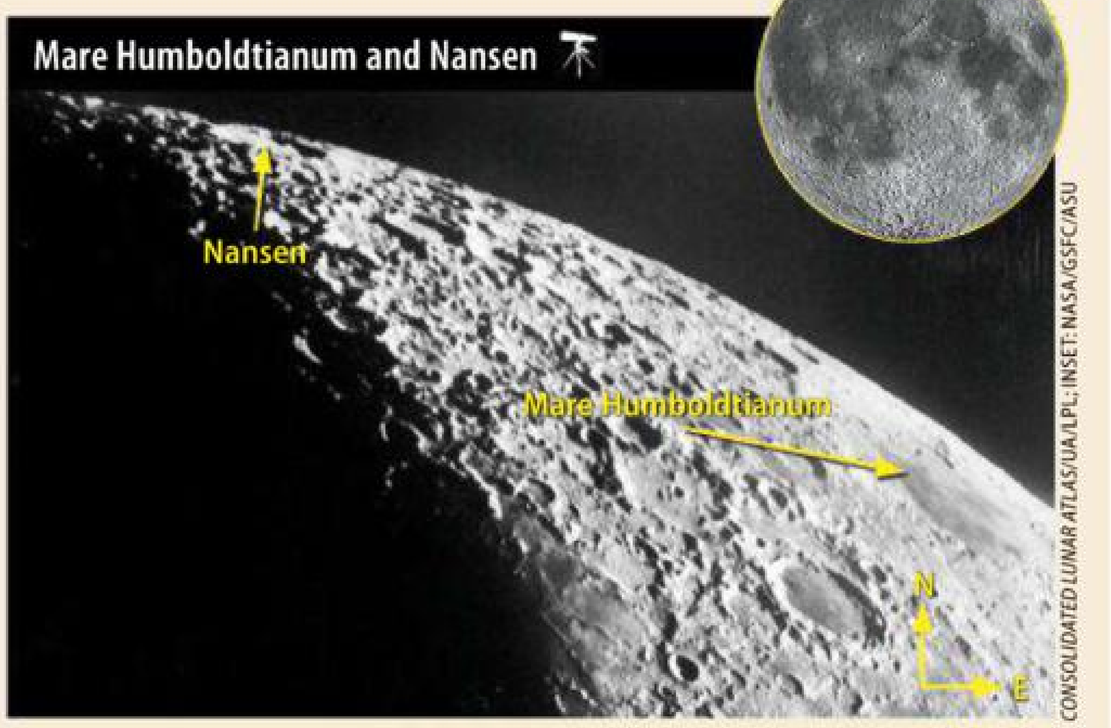
A big draw to solar system observing is the chance to see objects with a 3-D perspective. Nowhere is this effect greater than along the Moon's limb.

We gain the strongest sense of depth from shadows cast by tall crater rims onto the floors below. At low Sun angles, shadows appear so sharp and long that they actually exaggerate the relief. The effect led early selenographers to think that the lunar terrain is jagged. If you view the limb at high power, however, you'll see the profile is much smoother — bumpy, to be sure, but not saw-toothed.

Examine the waxing crescent Moon on the evening of May 2. The first thing that jumps out at you is sunrise on the magnificent Mare Crisium. After you gawk at its semicircle of peaks towering over an uneven floor, scan northward along the limb until you reach a large flat zone punctuated by a dark swath. This is Mare Humboldtianum, the flooded center of a large basin. Farther north and close to the cusp (where the crescent comes to a point) lies the crater Nansen. Named after Norwegian polar explorer Fridtjof Nansen, the crater's broad and tall rim casts a wall of shadow onto its floor.

The shadows retreat over the next few evenings, but so does Nansen itself. You'll also notice less real estate between the lunar limb and maria Humboldtianum and Crisium, as if the Moon is turning its face away from us. What's happening? Although the Moon spins at a constant rate, its orbital speed varies because it travels an elliptical path around Earth. In early May, the Moon is on the slower part of its journey. Astronomers call this apparent rolling motion "libration."

As Full Moon approaches, watch Mare Crisium librate closer to the limb. You can follow the changing orientation through binoculars or a telescope.



Mare Humboldtianum lies near the Moon's northeastern limb, where it comes into view just a few days past our satellite's New phase.

following Io, Europa, Ganymede, and Callisto any time Jupiter is visible, the most exciting views come when one or more moons pass in front of the planet or cast shadows onto the cloud tops.

A moon's black shadow is particularly easy to spot. A good observing opportunity comes the evening of May 5 when Ganymede's shadow treks across Jupiter's face. The black dot first touches the cloud tops at 10:08 P.M. EDT; 90 minutes later, the shadow appears near the disk's center.

If you watch throughout this period, you'll notice Europa approaching the planet's eastern limb. At 12:37 A.M. EDT, this moon begins a transit. Observers in western North America can view Ganymede's shadow and Europa complete their transits.

More often than not, all four moons shine against a dark background sky. One or two occasionally disappear

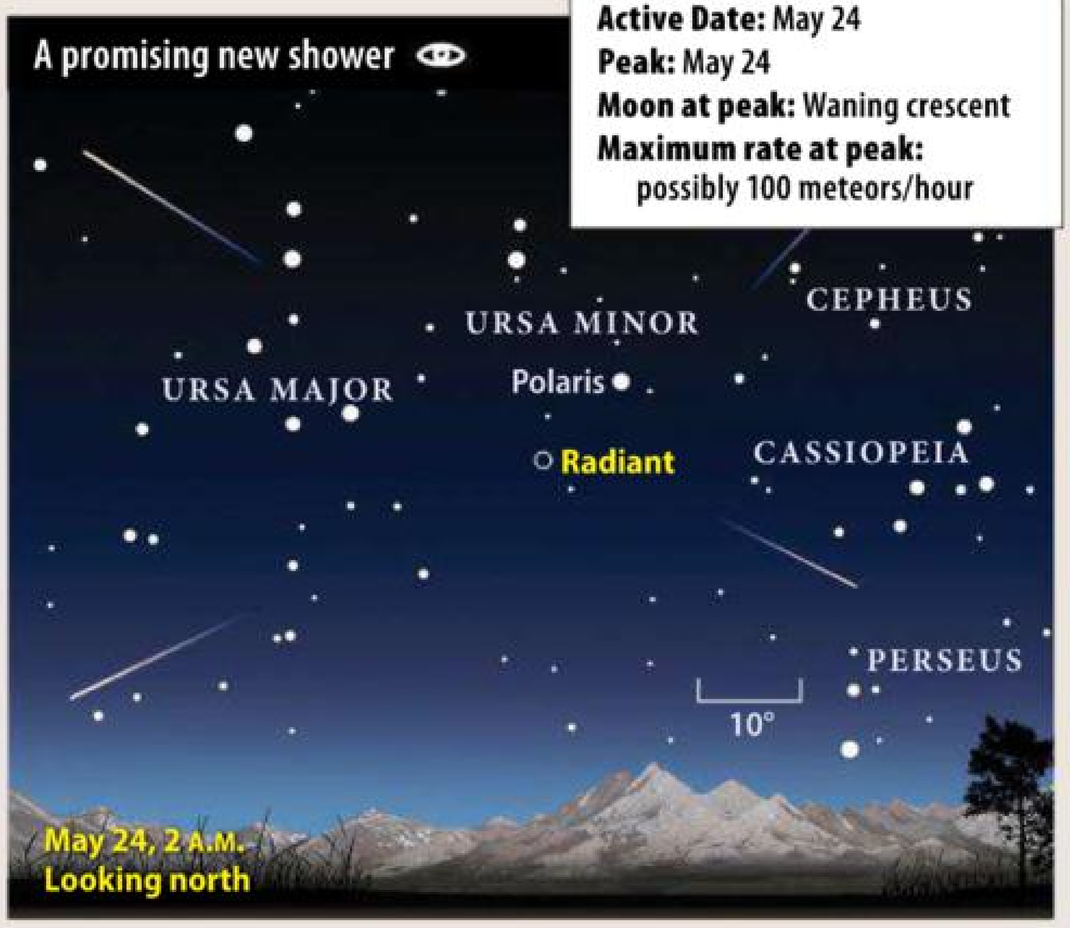
— *Continued on page 42*

METEOR**WATCH**

Could a new storm be brewing?

Two meteor shows should grace our skies this month. The first is a relatively known quantity. The Eta Aquarid shower peaks before dawn May 6 and could produce up to 40 meteors per hour under optimal conditions. The best views come under a dark sky after the waxing crescent Moon sets around 1:30 A.M. local daylight time. The shower is best from the Southern Hemisphere, where the radiant — the point from which the meteors appear to come — climbs high.

But a new shower could outduel the Eta Aquarids this year. Astronomers predict that Earth will pass through debris from Comet 209P/LINEAR before dawn May 24. The resulting shower could produce 100 meteors per hour or more. And with essentially no interference from a crescent Moon that rises around 3 A.M. local daylight time, viewing conditions will be excellent. The shower's radiant lies nearly due north near the border between Ursa Major and Camelopardalis.



The year's best meteor shower could occur May 24 when Earth encounters debris laid down by Comet 209P/LINEAR. *ASTRONOMY*: ROEN KELLY

OBSERVING HIGHLIGHT The second half of May provides Northern Hemisphere observers with some of their finest evening views of Mercury this year.

stevemaas.com

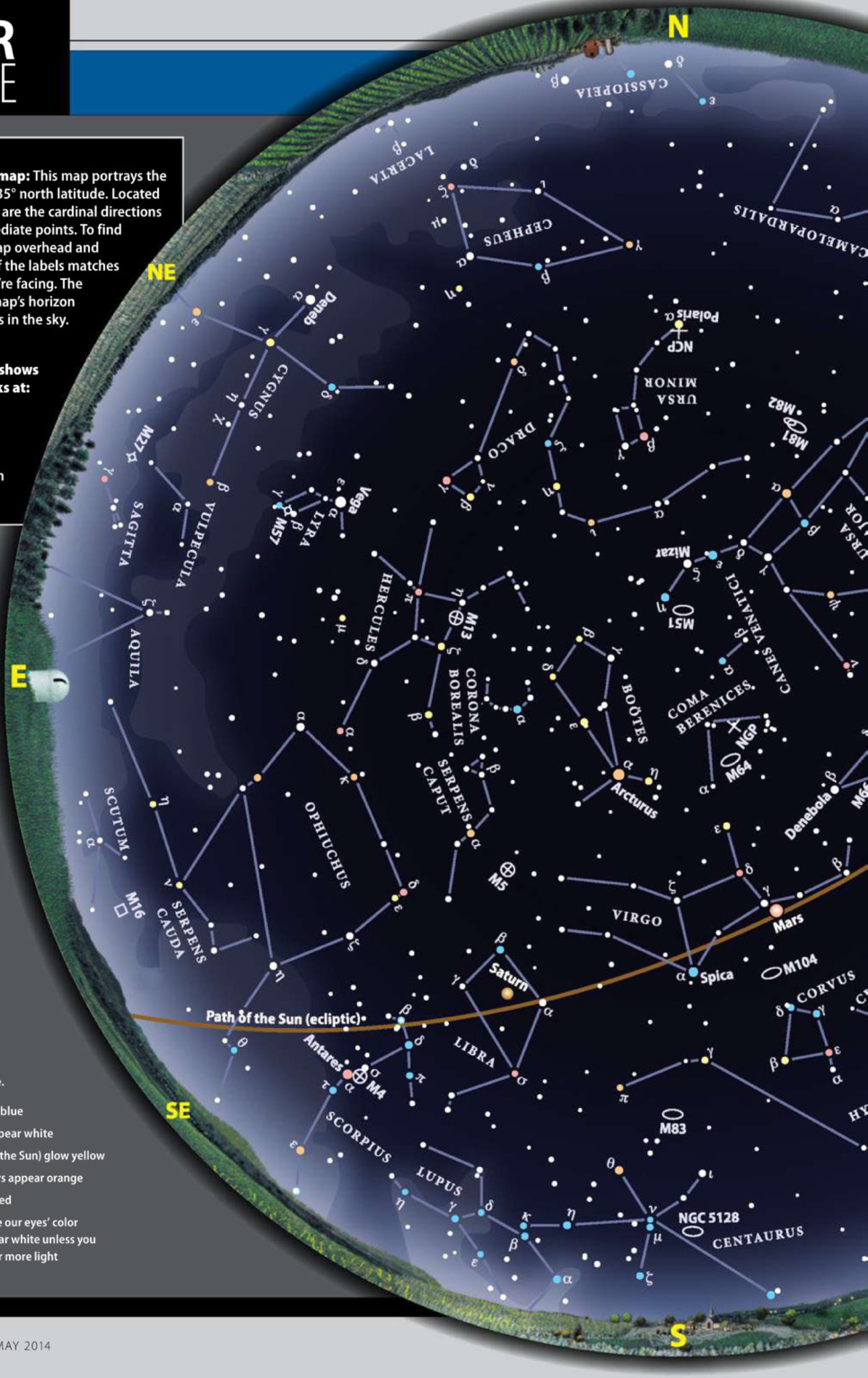
STAR DOME

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

midnight May 1
11 P.M. May 15
10 P.M. May 31

Planets are shown at midmonth



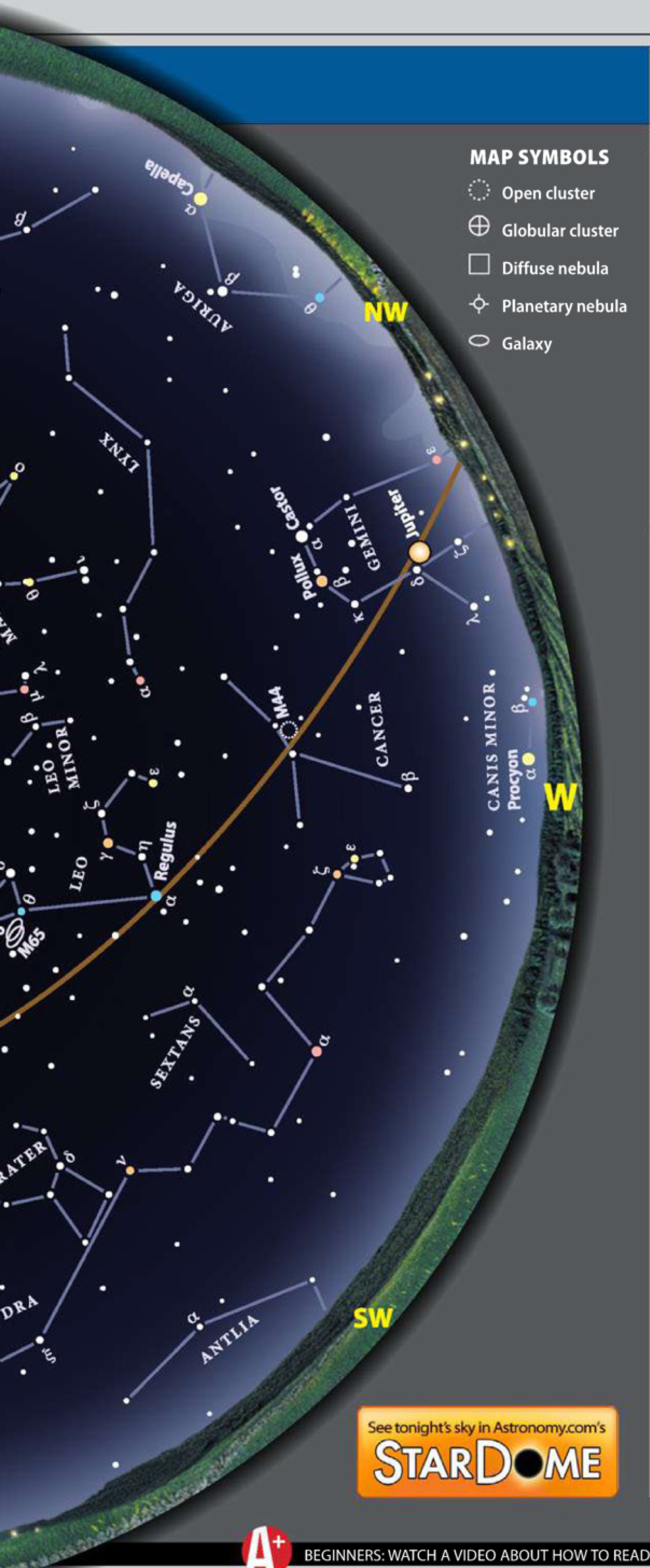
STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light



MAY 2014

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Calendar of events

4 The Moon passes 5° south of Jupiter, 10 A.M. EDT

6 Eta Aquarid meteor shower peaks

The Moon is at apogee (251,232 miles from Earth), 6:24 A.M. EDT

First Quarter Moon occurs at 11:15 P.M. EDT

SPECIAL OBSERVING DATE

10 Saturn reaches its 2014 peak, shining at magnitude 0.1 and appearing 18.7" across through a telescope (the rings span 42.4" and tilt 22° to our line of sight).

10 Saturn is at opposition, 2 P.M. EDT

11 The Moon passes 3° south of Mars, 10 A.M. EDT

13 Mercury passes 8° north of Aldebaran, noon EDT

14 The Moon passes 0.6° south of Saturn, 8 A.M. EDT

Full Moon occurs at 3:16 P.M. EDT

15 Venus passes 1.3° south of Uranus, 9 A.M. EDT

Asteroid Metis is at opposition, 10 A.M. EDT

18 The Moon is at perigee (228,107 miles from Earth), 7:57 A.M. EDT

21 Mars is stationary, 5 A.M. EDT

Last Quarter Moon occurs at 8:59 A.M. EDT

The Moon passes 5° north of Neptune, midnight EDT

24 Peak of meteor shower linked to Comet 209P/LINEAR

The Moon passes 1.9° north of Uranus, 4 P.M. EDT

25 Mercury is at greatest eastern elongation (23°), 3 A.M. EDT

The Moon passes 2° north of Venus, noon EDT

28 New Moon occurs at 2:40 P.M. EDT

30 The Moon passes 6° south of Mercury, noon EDT

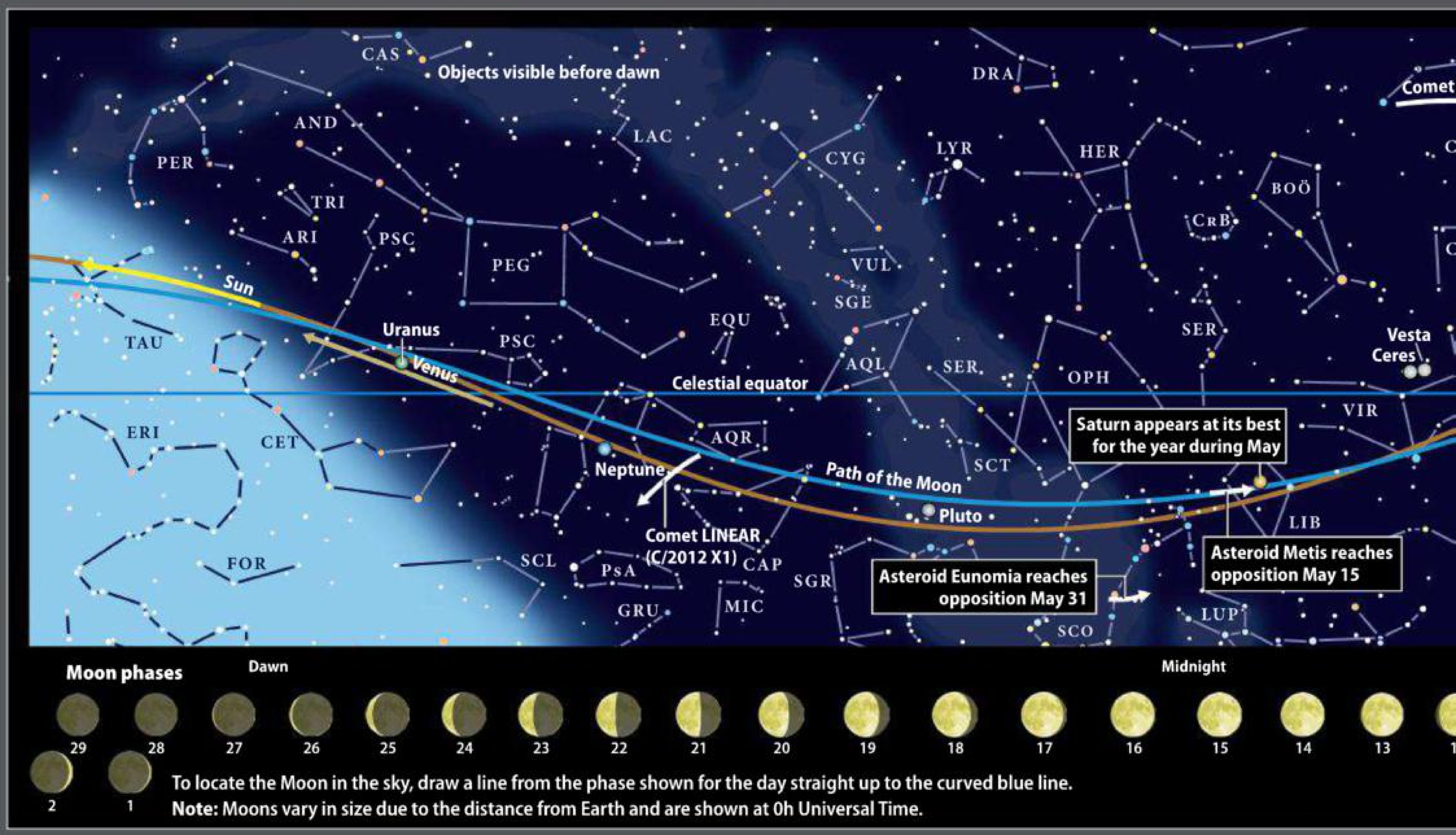
31 Asteroid Eunomia is at opposition, 2 P.M. EDT

See tonight's sky in Astronomy.com's STARDOME

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**

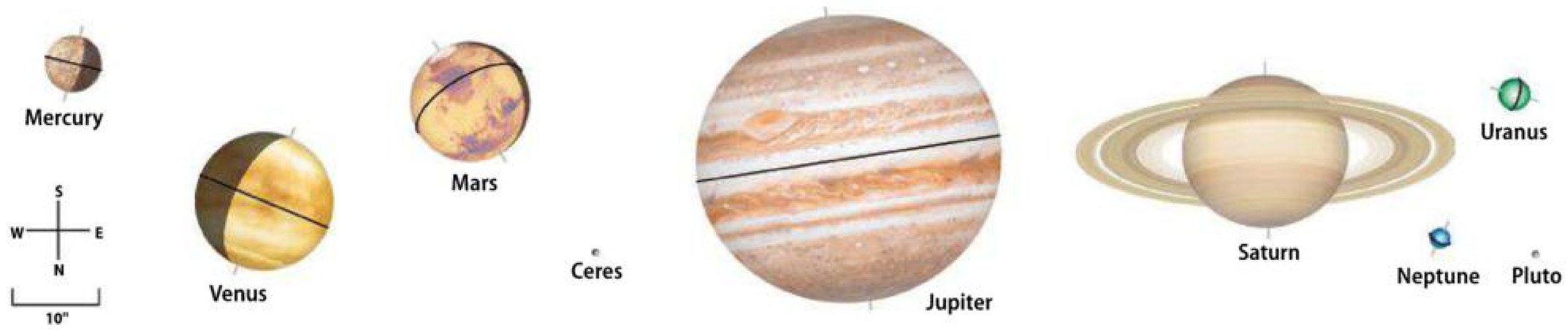
PATH OF THE PLANETS

The planets in May 2014



The planets in the sky

These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets for the dates in the data table at bottom. South is at the top to match the view through a telescope.

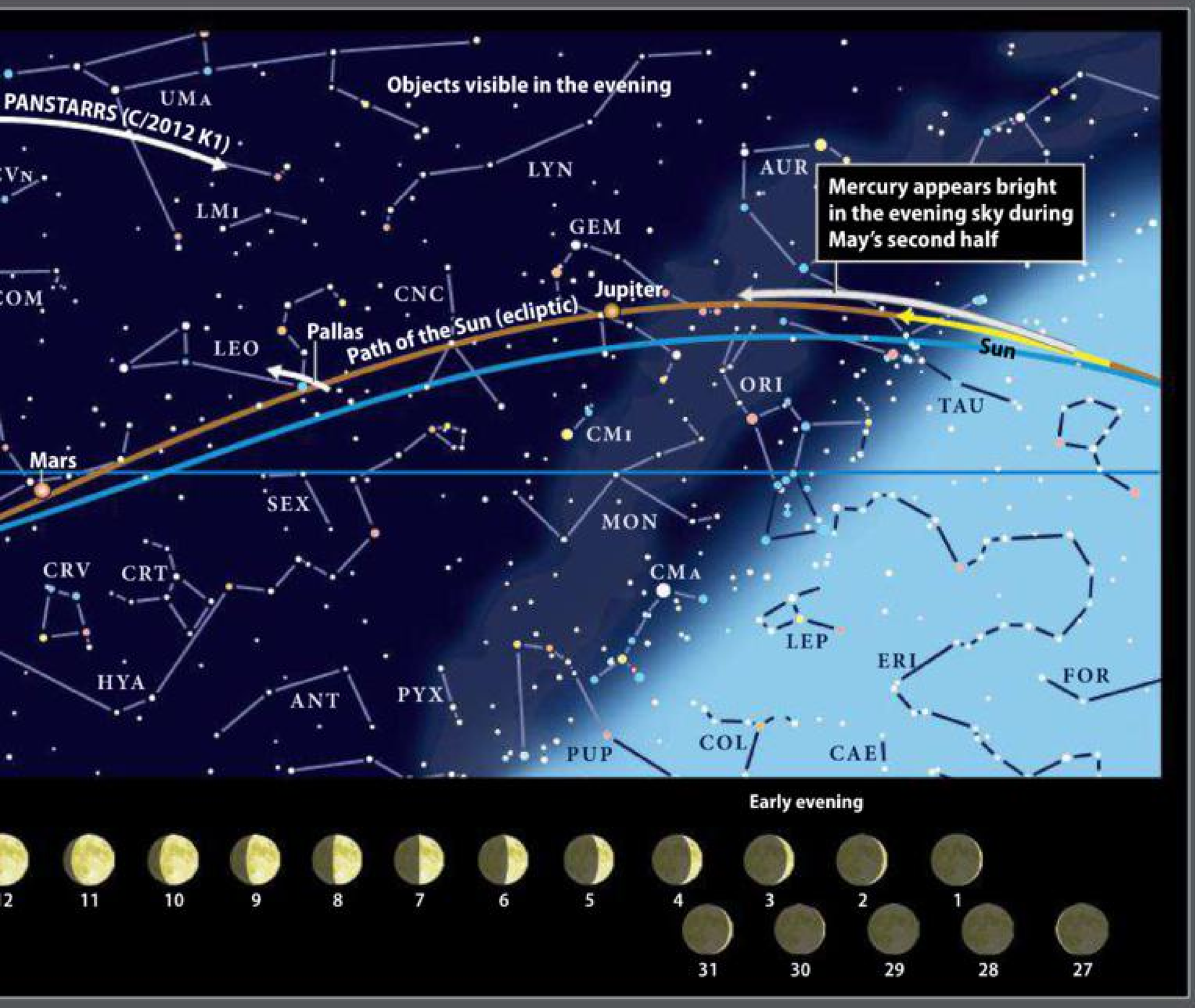


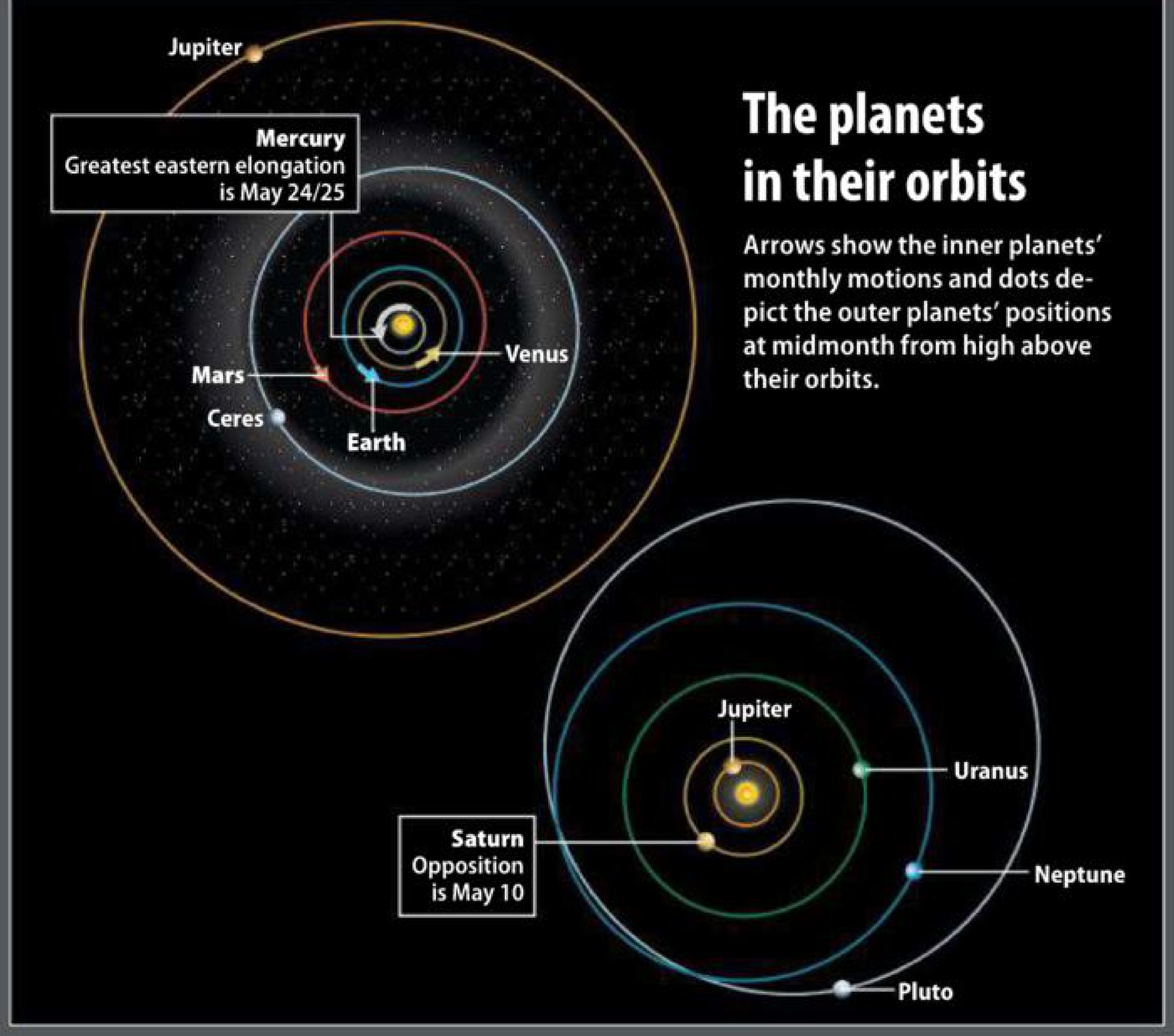
Planets	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	May 15	May 15	May 15	May 15	May 15	May 15	May 15	May 15	May 15
Magnitude	–0.6	–4.0	–0.9	7.5	–1.9	0.1	5.9	7.9	14.1
Angular size	6.4"	15.4"	13.4"	0.8"	34.1"	18.7"	3.4"	2.3"	0.1"
Illumination	63%	72%	95%	99%	99%	100%	100%	100%	100%
Distance (AU) from Earth	1.046	1.085	0.700	1.764	5.785	8.902	20.796	30.192	31.983
Distance (AU) from Sun	0.347	0.728	1.585	2.647	5.241	9.910	20.025	29.975	32.651
Right ascension (2000.0)	4h45.4m	0h52.4m	12h34.6m	13h29.6m	7h14.0m	15h11.0m	0h54.6m	22h36.7m	18h56.1m
Declination (2000.0)	24°38'	3°39'	–2°39'	3°31'	22°40'	–15°13'	5°08'	–9°31'	–20°08'

staremaps

stormart.com

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.



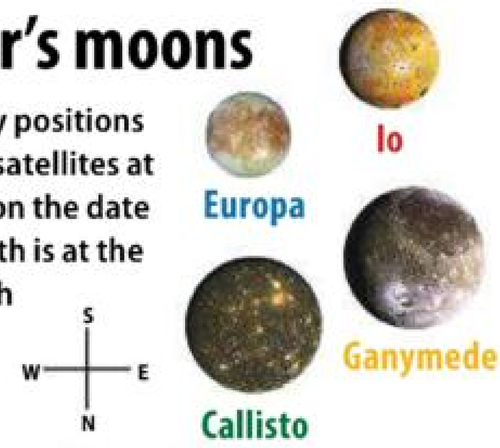


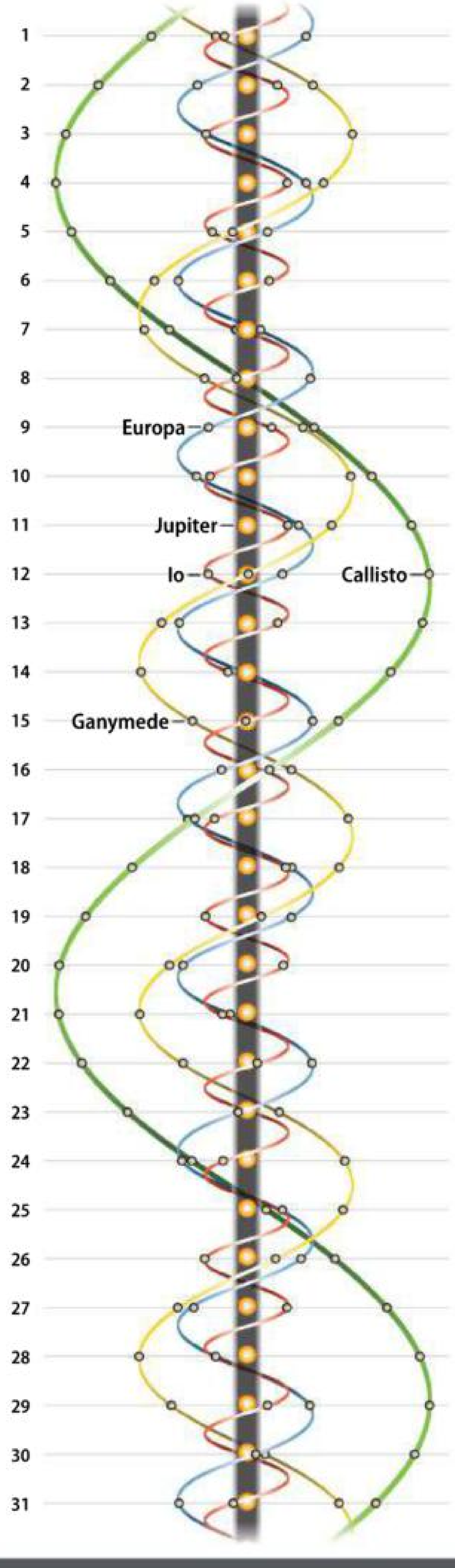
The planets in their orbits

Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at midmonth from high above their orbits.

Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on the date shown. South is at the top to match the view through a telescope.





ILLUSTRATIONS BY ASTRONOMY: ROEN KELLY

— *Continued from page 37*

WHEN TO VIEW THE PLANETS

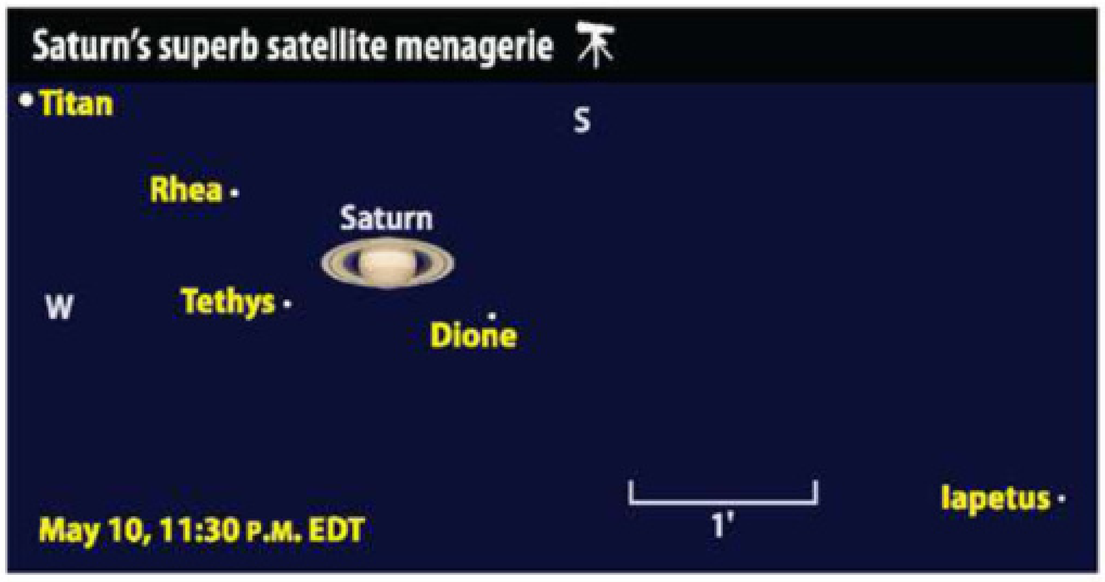
EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (northwest)	Mars (southwest)	Venus (east)
Mars (south)	Jupiter (northwest)	Saturn (southwest)
Jupiter (west)	Saturn (south)	Uranus (east)
Saturn (southeast)		Neptune (southeast)

from easy visibility when they pass in front of or behind Jupiter. Only rarely do three go missing, leaving just one moon set against the sky. You have a chance to witness such an event the evening of May 30 when Callisto lies well east of the planet but Europa is transiting Jupiter while the planet blocks both Io and Ganymede from view.

Callisto remains the only conspicuous satellite from 10:57 P.M. to 12:55 A.M. EDT. Midway through this period, however, you will see Europa's shadow start to transit the jovian disk. And sharp-eyed observers in western North America might briefly glimpse Ganymede. The solar system's largest moon reappears from behind Jupiter's wide disk at 9:00 P.M. PDT, only to be eclipsed by the giant planet's shadow three minutes later.

After viewing Jupiter, shift your gaze about 90° east to find **Mars**. The Red Planet shines brightly among the background stars of Virgo the Maiden, appearing high in the southeastern sky as darkness falls in early May.

Mars reached opposition and peak visibility in April, and it remains impressive during May. But no other outer planet changes as quickly as Mars does. It shines at magnitude –1.2 May 1 and dims to magnitude –0.5, a drop of nearly 50 percent, by the 31st. Still, that's brighter than any star once Sirius sets.



Saturn's five brightest moons should all show up through 4-inch and larger scopes the night of the ringed planet's May 10 opposition. *ASTRONOMY:* ROEN KELLY

The planet's apparent diameter also shrinks during May, from 14.6" to 11.9". That's still big enough to show surface features clearly through 4-inch and larger telescopes, particularly during moments of good seeing when turbulence in Earth's atmosphere dies down. The best times to view are when Mars climbs highest in the south, from midevening until 1 or 2 A.M.

The easiest feature to see on most nights will be the north polar cap. The white expanse stands out despite the direct sunlight beating down during the northern hemisphere's summer. The cap appears particularly prominent now because the planet's north pole tilts 25° in Earth's direction.

Mars rotates on its axis once every 24.7 hours, so its visible hemisphere shifts slightly from night to night. Syrtis Major, the planet's best known and most conspicuous dark feature, appears front and center during May's first week. It is visible as soon as the sky grows dark and remains on view until well past midnight.

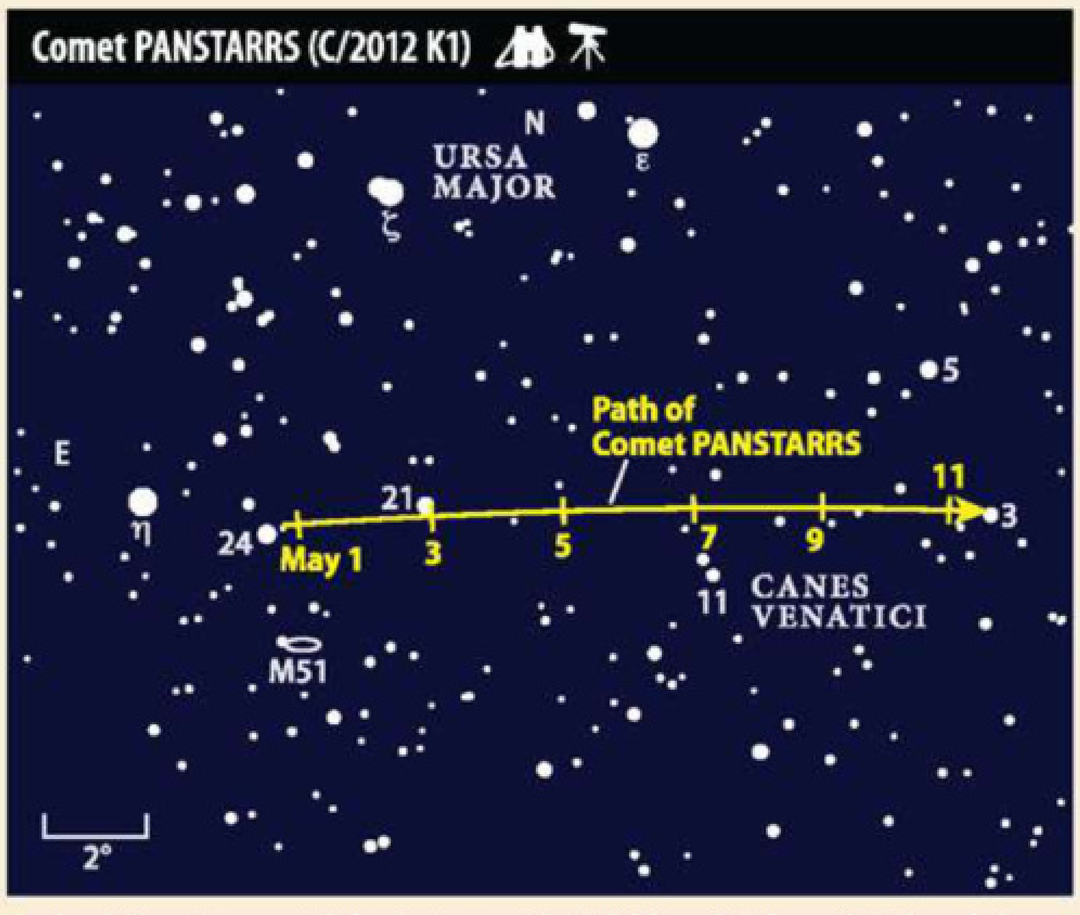
COMETSEARCH

A frozen visitor sweeps past the Whirlpool

Astroimagers should mark their calendars for May 1. On that evening, Comet PANSTARRS (C/2012 K1) glides just 2° north of the beautiful Whirlpool Galaxy (M51) in Canes Venatici. The pair remain reasonably close a night or two on either side of the 1st. The grand spiral galaxy glows at 8th magnitude, coincidentally the same brightness as the vastly smaller but closer ball of ice and dust sailing through the inner solar system. From a dark-sky site, the two show up through binoculars as similarly round, gray cotton balls south and west of 2nd-magnitude Eta (η) Ursae Majoris, the star at the end of the Big Dipper's handle.

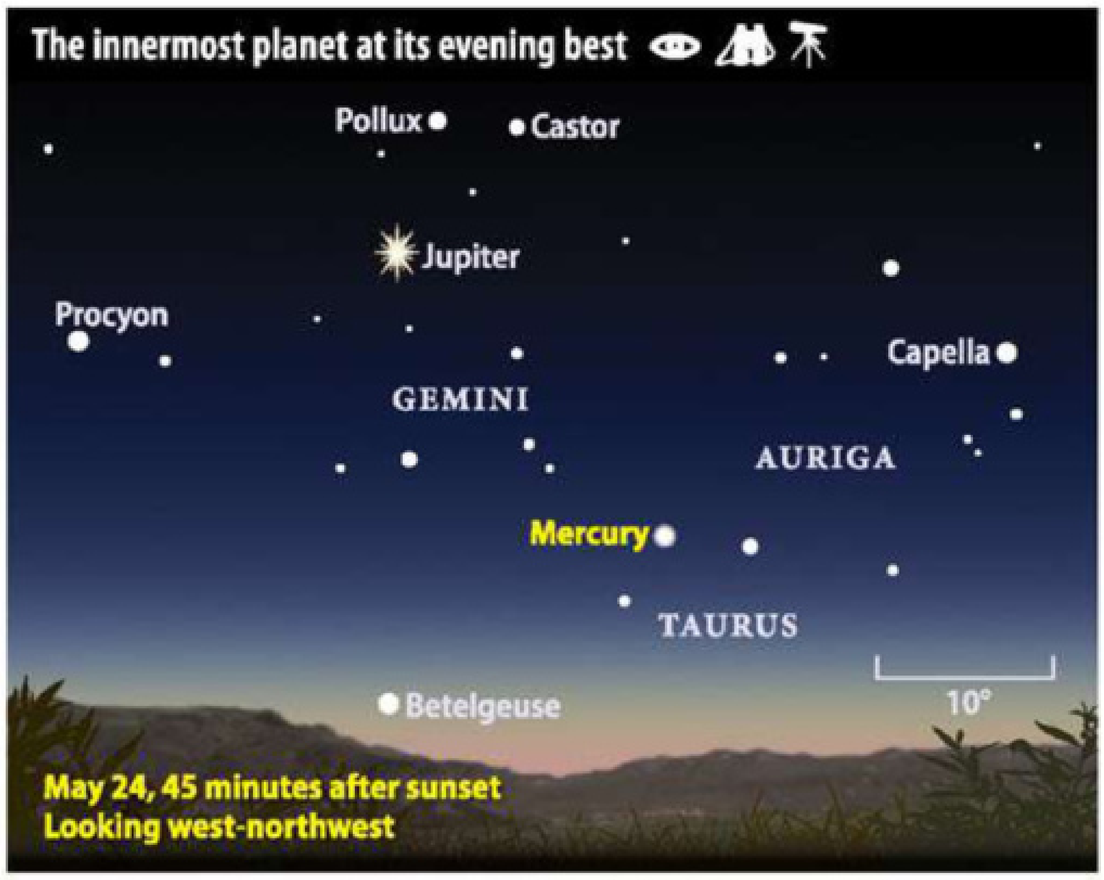
As you apply more aperture and magnification to both objects, they look increasingly different. Compare and contrast their shapes and characters. If you ignore M51's small companion galaxy, NGC 5195, the Whirlpool appears quite round and has a sharply defined outer edge. The comet, on the other hand, looks noticeably lopsided, with a curved bright northern edge and a broad fan that spreads southward before diffusing into the background sky.

The central parts of both the comet and galaxy grow brighter toward the middle. The comet's coma is a ball of gas and dust that cloaks the dark surface of the comet's nucleus. A dark object also lurks at the Whirlpool's center, but even the Hubble Space Telescope can't image the supermassive black hole that lies in this galaxy's core.



Spring's finest comet slides between the Whirlpool Galaxy (M51) and the Big Dipper's handle during early May. *ASTRONOMY:* ROEN KELLY

In the second half of May, C/2012 K1 departs Canes Venatici and enters the modestly rich galaxy country south of the Big Dipper's bowl. On the 20th, the comet shares a high-power field of view with the 10th-magnitude spiral galaxy NGC 3726.



Mercury puts on a nice show on evenings during May's second half when it lies among the background stars of Taurus the Bull. *ASTRONOMY:* ROEN KELLY

Evening highlights during May's second week include the bright plains of Elysium and a dark band to its south called Mare Cimmerium.

Saturn lies among the background stars of Libra the Balance, one constellation east of Mars' current home in Virgo. The ringed world reaches opposition May 10, when it lies opposite the Sun in our sky. As you might guess, this means the planet rises at sunset, climbs highest in the south around 1 A.M. local daylight time, and sets as the Sun comes up. Opposition also brings Saturn closest to Earth, so it shines brightest for the year (at magnitude 0.1).

Opposition marks the peak time for observing any outer planet. Not only does a distant world then remain visible all night and shine brightest, but it also appears largest through a telescope. On May 10, Saturn's disk measures 18.7" across while its stunning ring system spans 42.4". The rings tilt 22° to our line of sight and reveal exquisite detail through any scope. Although the planet shrinks as we get further from opposition, the change is barely detectable — the ring system's diameter drops only 0.3" by month's end.

Saturn also has several moons that show up through small instruments. Any telescope reveals 8th-magnitude Titan, while a 4-inch scope brings Tethys, Dione, and Rhea — all 10th-magnitude satellites — into view. A 4-inch instrument also should show you Iapetus, which glows at 11th magnitude when it passes north of Saturn on May 6. For more information about viewing the ringed world, turn to "See Saturn in prime time" on p. 62.

As Saturn dips toward the western horizon with the approach of dawn, **Neptune** climbs in the southeastern sky. The distant planet rises about three hours before the Sun in mid-May and appears some 15° high as twilight commences. You'll need binoculars or a telescope to spot magnitude 7.9 Neptune.

Look for it on the line that joins 4th-magnitude Lambda (λ) Aquarii and 5th-magnitude Sigma (σ) Aqr. Neptune stands 2° from the fainter star. The planet spends May inside a triangle of 7th-magnitude suns.

Venus rises about 100 minutes before the Sun in mid-May, just as twilight starts to paint the sky. But don't let dawn's approach scare you away — the planet appears so bright, at magnitude –4.0, that it remains prominent up to a half-hour before sunrise. Point a telescope at Venus, and you'll see a 15"-diameter disk that appears nearly three-quarters illuminated.

Our final planet this month lurks in Venus' vicinity. **Uranus** lies 1.3° north of Venus on May 15. With an exceptionally clear sky and an unobstructed eastern horizon, you should be able to spot the distant planet through 7x50 binoculars.

Uranus glows at magnitude 5.9 — 0.01 percent as bright as its neighbor. The outer world will be easier to find in coming months as it climbs higher in a dark sky.

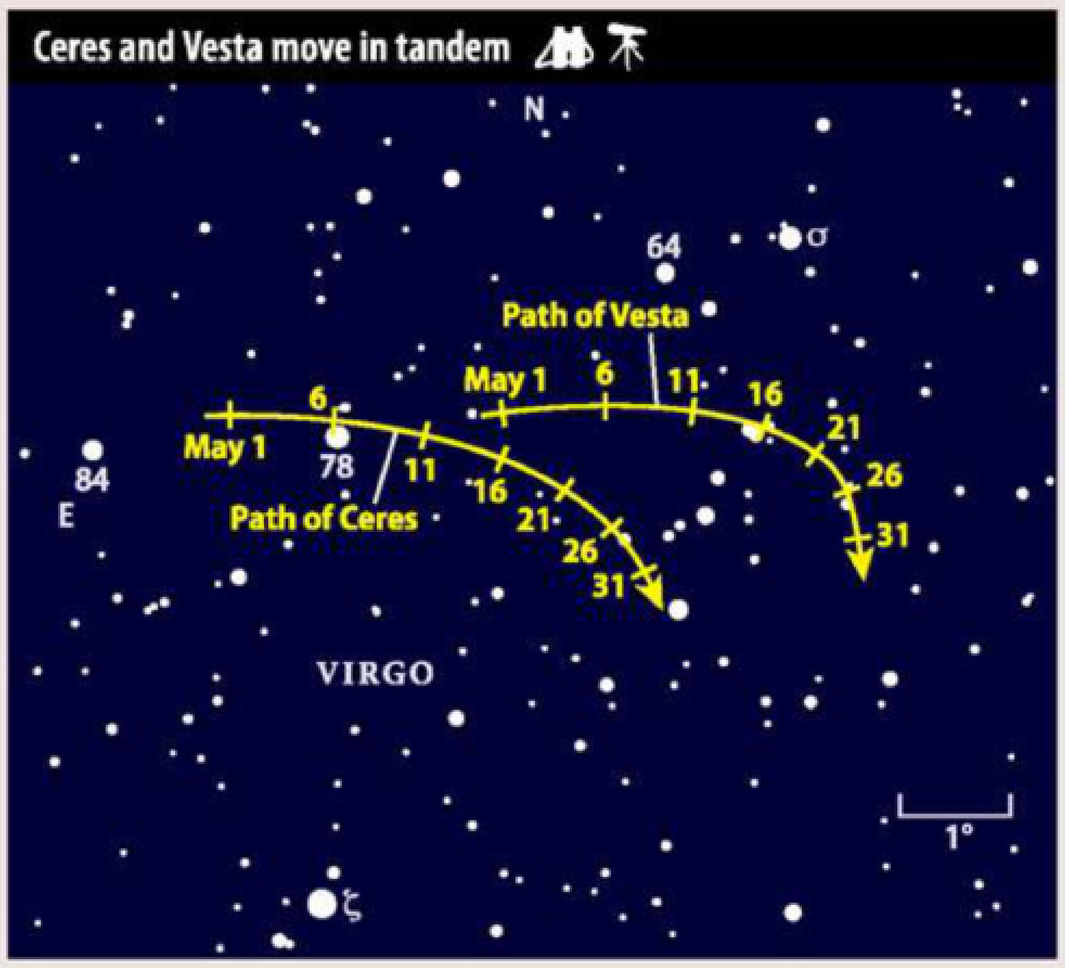
LOCATING**ASTEROIDS**

When (minor) planets align

Asteroids 1 Ceres and 4 Vesta troll a relatively sparse region of northern Virgo during May, making the two brightest asteroids fairly easy to spot. They lie between 2° and 3° apart and some 15° northeast of brilliant Mars, placing them about halfway up in the southeastern sky after darkness falls. Although the two reached opposition and peak brightness in mid-April, they remain fine targets in May.

Are you up for a challenge? Try to see Vesta move with just your naked eyes. This asteroid shines brighter than the typical magnitude 6.5 limit for an average dark sky. To detect its motion, you need to observe it on two moonless nights. Make your first sighting in early May and the second in the month's final week. Locate Vesta on the map below, and then make a chart that includes four or five of the brighter stars in its area. Memorize the chart, and use it as a framework for your search.

Ceres is slightly out of naked-eye range, but it shows up easily through binoculars in the same field of view as Vesta. You can track the steady motions of both objects through a 3-inch telescope from the suburbs. For much more on observing these asteroids this spring and summer, see "View Ceres and Vesta at their best" on p. 52.



The two brightest asteroids appear within 3° of each other in May as they trek westward against the backdrop of Virgo the Maiden. *ASTRONOMY:* ROEN KELLY

GET DAILY UPDATES ON YOUR NIGHT SKY AT **www.Astronomy.com/skythisweek.**

A dream night Discovery Channel

storemags.com

The sky above Happy Jack, Arizona, is dark and steady — perfect for observing with the giant Discovery Channel Telescope. The telescope peers through an opening in the 73-foot-tall (22 meters) housing (inset). ALL PHOTOGRAPHS: TOM POLAKIS

with the Telescope



Few observers are ever able to use an instrument with a 14-foot mirror. For one night, **Tom Polakis** saw how the universe looks through such a behemoth.

When I began in amateur astronomy, no photograph was more enticing than that of American astronomer Edwin Hubble in the prime-focus cage of the 200-inch Hale Telescope on Palomar Mountain in California. If my 3-inch reflector showed Saturn's rings so clearly, what would they look like through such an observatory scope? What details are buried in the Ring Nebula? Thirty-five years later, I jumped on a rare opportunity to use an instrument even better than the 200-inch.

Lowell Observatory's new Discovery Channel Telescope (DCT) lies 40 miles (60 kilometers) southeast of Flagstaff, Arizona, and sits a couple hundred feet higher than the surrounding terrain at 7,667 feet (2,337 meters) above sea level. This location makes the seeing (atmospheric steadiness) several times better than it is at most star party sites. The DCT's meniscus mirror spans 168 inches (4.3 meters) across a 4-inch (0.1m) thickness, and it is actively cooled to within 2° Fahrenheit (1.1° Celsius) of the ambient temperature. Surprised to learn that the instrument cube includes a visual back, which allows observers to use their eyes and not just a camera or other instrument to view the skies, I was prompted to make a plan to take advantage of that ability.

In June 2013, the DCT was well into its engineering phase, observing 80 percent of the time, a number that would increase to full capacity within months. This was the sweet spot for proposing an amateur-astronomer observing run. When I contacted DCT Commissioning Scientist Stephen Levine with a humble proposal on a Tuesday, he replied, "How about next Monday night?"

Tom Polakis *is an accomplished visual observer and author of the* Astronomy *series "Celestial Portraits," which ran from 1998 to 2004.*

Storem

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The Discovery Channel Telescope's housing protects it from the elements. It sits on a plateau above the surrounding landscape.

How the DCT came to be

The DCT is not intended to be a visual observing instrument, although it does project stunning images onto the eye. It is a research-grade observatory — the fifth-largest one, in fact, in the continental United States. Its story began in February 2003, when Lowell Observatory and Discovery Communications — the Discovery Channel's parent company — became business partners in its construction. In addition to the $10 million the network donated, its chief, John Hendricks, and his wife, Maureen Donohue, contributed to the tune of $6 million. The telescope cost $53 million and will be used by astronomers from Lowell and its partner institutions, Boston University, the University of Maryland, the University of Toledo, and Northern Arizona University.

In November 2004, the collaboration began improving the road up to the telescope site, an old cinder cone near the town of Happy Jack, so that the sensitive, precise equipment — once it existed — would not sustain damage on the ride up to its home. Almost a year later, construction began on the DCT's 73-foot-tall (22m), 65-foot-diameter (20m) housing. Around the same time, Corning, Inc., located in Corning, New York, finished the primary mirror blank — a piece of glass the rough size and shape of the desired final mirror.

The blank then needed to be polished to a precise, smooth surface. The DCT team decided, in 2006, to entrust this delicate work to those at the University of Arizona's Optical Engineering and Fabrication Facility, who spent three years polishing before they delivered the final mirror — which weighs 6,700 pounds (3,000 kilograms) — to Happy Jack in June 2010. Once it was there, engineers coated its front surface with 4 millionths of an inch of aluminum and connected it with the rest of the telescope. By February 2012, the DCT was finished, and two months later it was fully operational, celebrating its first light with a July gala.

The DCT's instruments can see a wide range of wavelengths, from the shortest optical to the longest near-infrared. Some of the things scientists are using its light-collecting abilities to search for are Kuiper Belt objects — balls of ice and rock that live beyond the orbit of Neptune, like dwarf planets Pluto and Makemake — and the universe's smallest galaxies. But investigating these dim, distant objects requires cameras, integration times, and filters, and my night at the DCT was about the telescope itself — its sheer size — and not the equipment attached to it. I wanted to see how different the universe looks to the eye when such a huge mirror is collecting its light.

Telescope trip

The two days before my group — an accomplished set of visual observers including my wife, Jennifer, Saguaro Astronomy Club President Mike Collins, and astronomy sketcher Jeremy Perez — was to arrive featured the first rain in Happy Jack in months. Our observing day — June 17, 2013 — though, dawned without a cloud, and visibility exceeded 100 miles (160km). When we arrived at the site two hours before sunset, the prevailing southwest wind blew steadily, foretelling stable air.

Having observed in a number of conventional hemispherical domes with thin slits over the years, my impression has usually been that the experience is disorienting and even stuffy. I want to be out under the night sky, looking up with unaided eyes when I'm not at the eyepiece. Modern enclosures like the DCT's enable such viewing — not for the aesthetic enjoyment of amateur astronomers, but to ventilate the telescope better. As long as the wind stays low, the giant shutters are open, enabling views of a pristine night sky between turns at the eyepiece when we weren't marveling at the telescope.

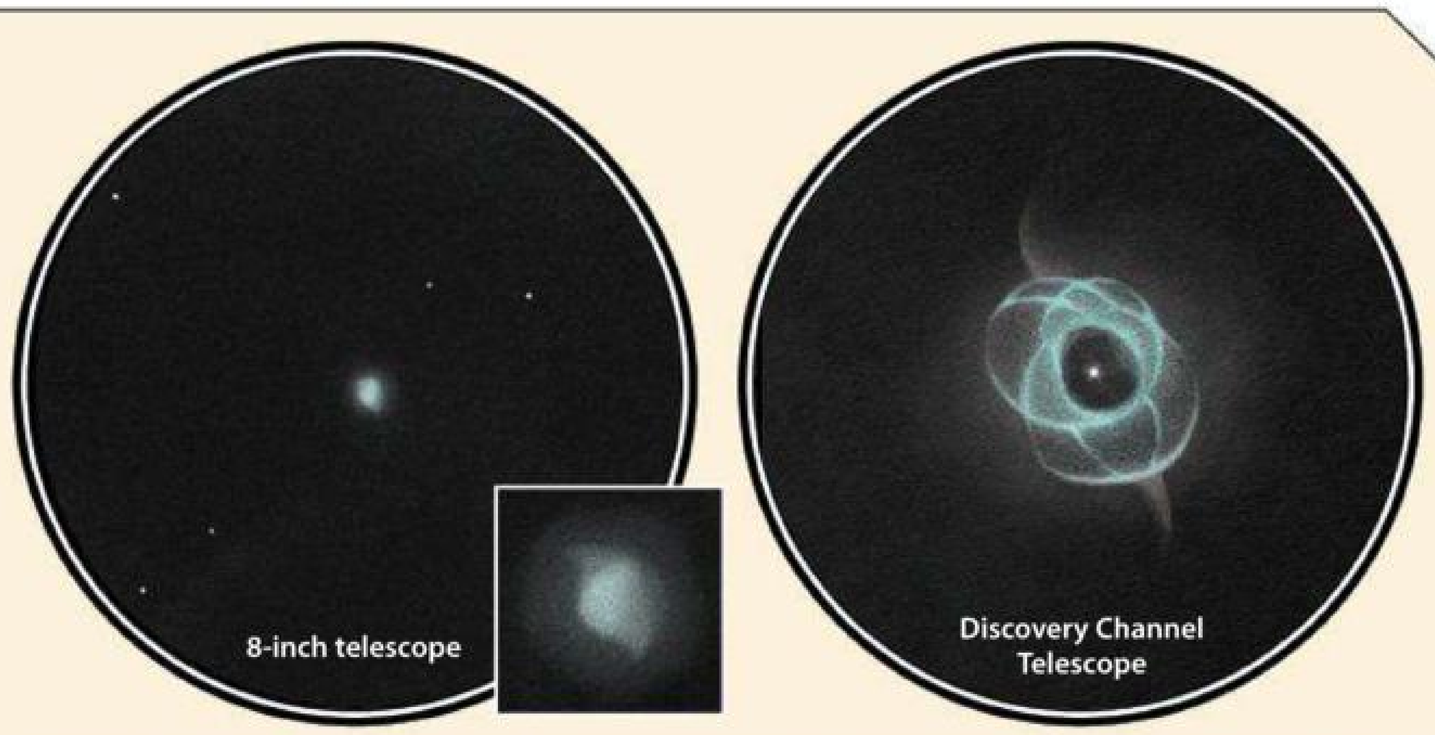
Through the 4.3-meter DCT, which has 26 meters of focal length, small objects with high surface brightness — like planetary nebulae and globular clusters — look best. The 30mm eyepiece that we used most of the night provided a magnification of 865x and a field of view spanning less than 6 arcminutes. Objects with large angular sizes, such as the Andromeda Galaxy (M31), are much better framed in amateur scopes, with their wider fields of view. Before we began our observing run, I made a target list of 75 objects extracted from the "Celestial Portraits" series I wrote for *Astronomy* between 1998 and 2004, knowing we'd only have time for a dozen of them.



Next to the instruments that transform the universe's photons into pixels is a visual back that allows observers like author Tom Polakis to look directly through the Discovery Channel Telescope and into space.

Storemags

Eyes on the sky By 6 P.M., 90 minutes before sunset, we commenced our observing run with a crater on the gibbous Moon. It showed the poor contrast daylight always presents. Levine used a laptop computer to slew the scope over to Saturn, which revealed more intricate details as sunset approached. The most striking difference between this telescope and small personal ones was the DCT's ability to reveal subtle color gradations, which were visible in both the planet's globe and its rings. The north polar region was a dark gray, and multiple bands southward to the equator showed shades ranging from brown to light beige. Structure in the rings was magnificent. The outermost A ring showed the Encke Minimum — a dim region in the middle of the large ring — as a thin, low-contrast band. After our eyes traversed the gaping Cassini Division, the B ring began to reveal the phonograph-record structure that shows up in Hubble Space Telescope images. Still farther in was the dark gray Crepe ring, which stood out against the even darker space separating it from the globe. At the edge of the field, Saturn's moon Titan resolved into a featureless disk, less than an arcsecond across.



Through an 8-inch Newtonian, NGC 6543 appears as a bright core with a dimmer outer structure, but through the Discovery Channel Telescope, intersecting loops popped out.

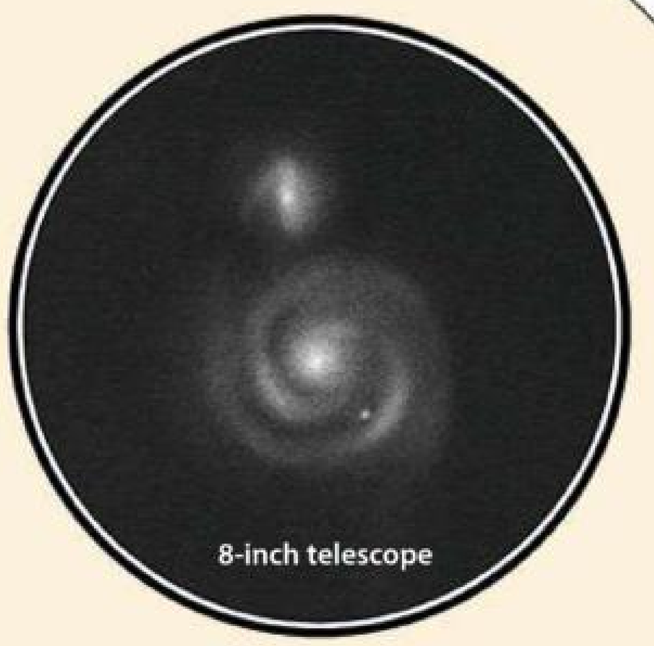
NGC 6543 Our first deep-sky object was the Cat's Eye Nebula (NGC 6543). Bright planetary nebulae like this often present a blue-green color through amateur telescopes, but with the DCT's aperture, it popped out. Two thin racetracks surrounded the central star. Two larger, overlapping circular rings that were equally thin hung to the northeast and southwest of center. All of this structure was overlaid on bright nebulosity that diminished but did not disappear, all the way to the edge of the field. About 2 arcminutes due west of the central star, we could see IC 4677, which looks like an elliptical galaxy but is actually a bright concentration in the outer halo of the planetary.



Abell 1656 The Coma galaxy cluster (Abell 1656) is more than 300 million light-years away. Surrounding its second-brightest member, 12th-magnitude NGC 4874, are a dozen faint galaxies, and the DCT's tiny field of view contained all of them. They have a wide variety of sizes and orientations, but even the large scope was unable to tease out any details.

The group could see all 12 of the faint Coma cluster galaxies that were in the Discovery Channel Telescope's field of view.

ALL SKETCHES: JEREMY PEREZ



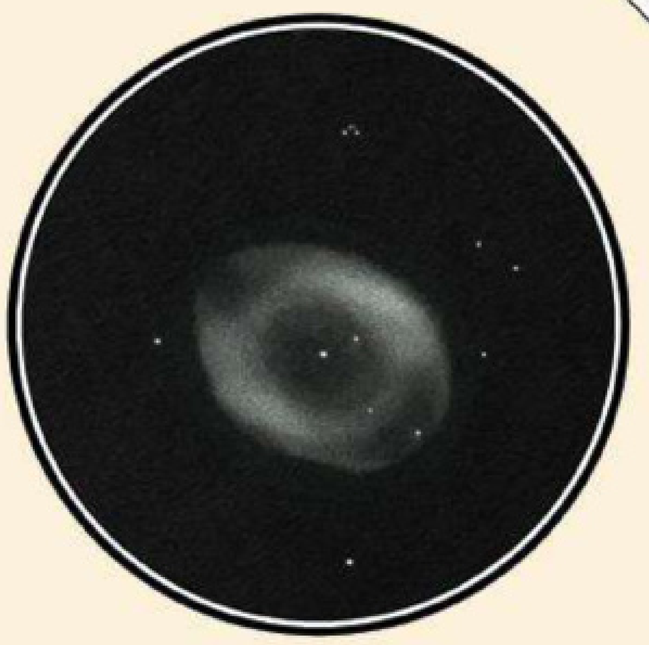


The Whirlpool Galaxy's (M51) arms were clear through both the 8-inch telescope and the Discovery Channel Telescope, but the bright associations and star-forming regions stood out through the latter.

M51 The Whirlpool Galaxy (M51) is a favorite among backyard observers. Large amateur telescopes show a bright unresolved core surrounded by arcing spiral arms. Because it has a field of view too small to offer good context, I wasn't expecting the DCT to show much, but I was happy to be proven wrong. The central 2 arcminutes were the most interesting, with intricate, flocculent structure, all spiraling off the blazing core in the same direction as the familiar inner arms, which were at the outer edge of the field. These inner arms contain a number of visible stellar associations and ionized hydrogen (HII) regions. The outer arms did not look like arcs; rather, they appeared to be made of several connected linear segments, also containing obvious HII regions, where stars form. A short pan brought in the companion galaxy, NGC 5195. Its core shines brighter than M51's, and I could see an elongated vivid yellow haze surrounding it. The "connecting" arm from M51 entered the field from the south and pointed east of the core, a dark lane separating the two.

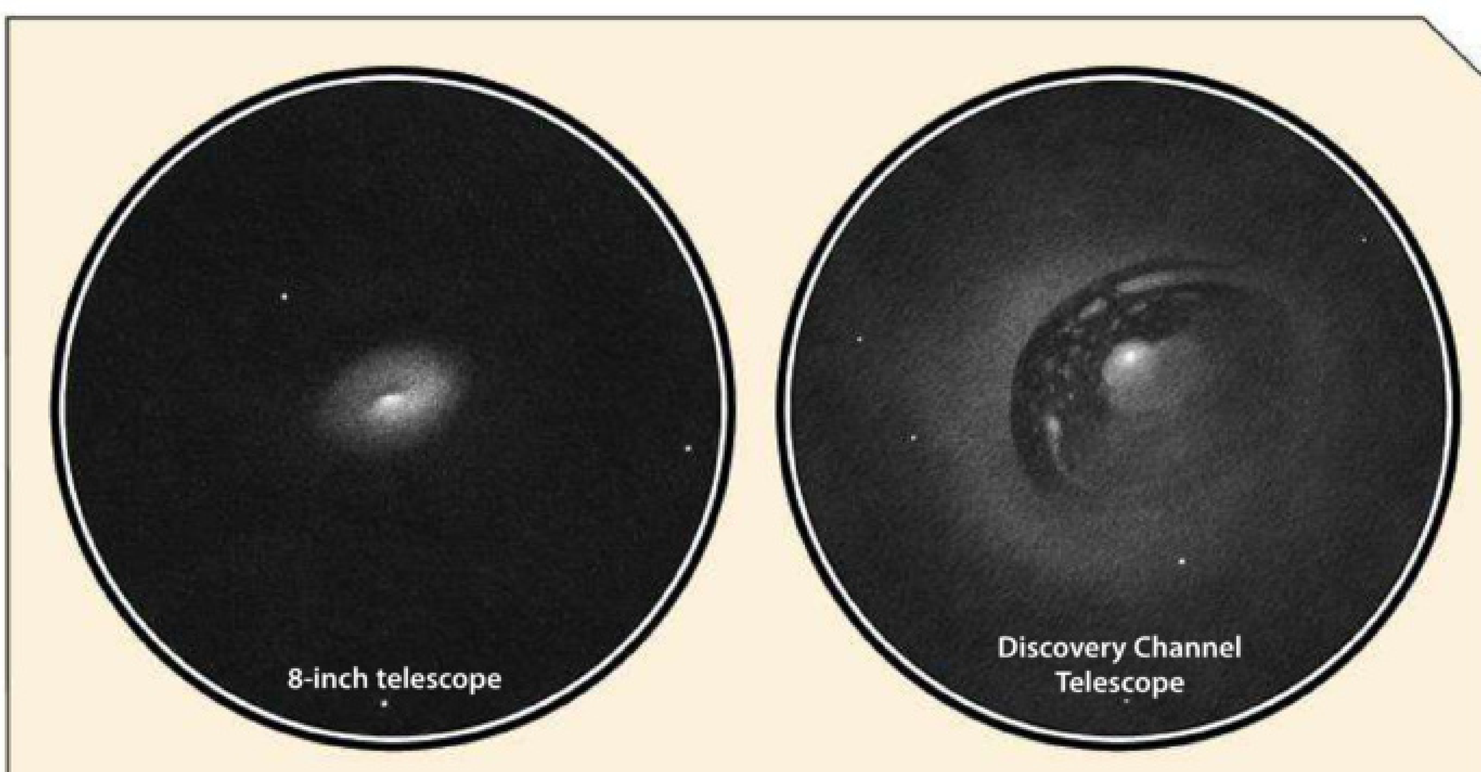


Astrosketcher Jeremy Perez takes his turn at the eyepiece, documenting the differences between the views through an observatory-grade scope and a personal one.



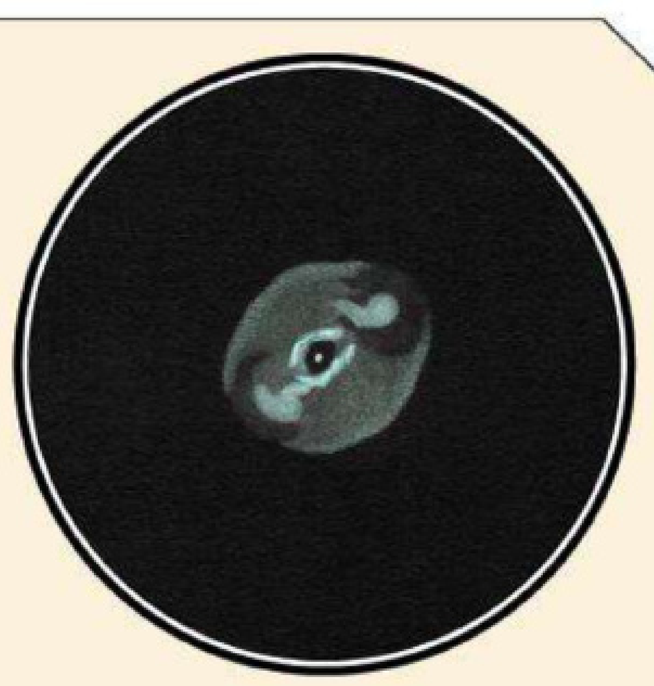
The Ring Nebula (M57) showed faint red coloration on its edges when viewed through the Discovery Channel Telescope.

M57 Viewed through 4.3 meters of aperture, the Ring Nebula (M57) initially offered few surprises, showing little color and the familiar circular outline. The central star required no effort to see, and another star in the doughnut hole and two more on the bright surface easily broke through the darkness. But upon closer inspection, we saw that the dim center had a ragged edge and was immersed in a haze brighter than the surrounding sky. More luminous areas appeared along the short axis, and the outermost edge showed a subtly red hue.



The Blackeye Galaxy's (M64) black eye — a dark region between its arms and its center — wasn't visible through an 8-inch telescope, but its details shone through with the Discovery Channel Telescope.

M64 Next on the observing list was the Blackeye Galaxy (M64), so named for the wide, dark lane that separates the galaxy's spiral arms and the core. When viewed through a smaller scope, the track remains a featureless black strip. When we viewed it through the much larger DCT, however, this lane appeared filled with detail, including a thin broken chain of knots at its outer edge. Both the inner and outer edges of the lane were irregularly serrated. The "black eye" continued all the way around to the far side of the spiral galaxy, where it appeared broader and not nearly as pronounced.



Rings of texture made NGC 6826 a treat through the Discovery Channel Telescope.

NGC 6826 High in Cygnus, NGC 6826 is sometimes called the Blinking Planetary. The DCT showed a bright blue disk surrounding the central star. The texture appeared mottled, with brighter, ruddy lobes halfway out along the long axis. One-quarter of the way from the center was a thin ring whose structure was reminiscent of our earlier view of the Cat's Eye Nebula.

THE 411: DISCOVERY CHANNEL TELESCOPE

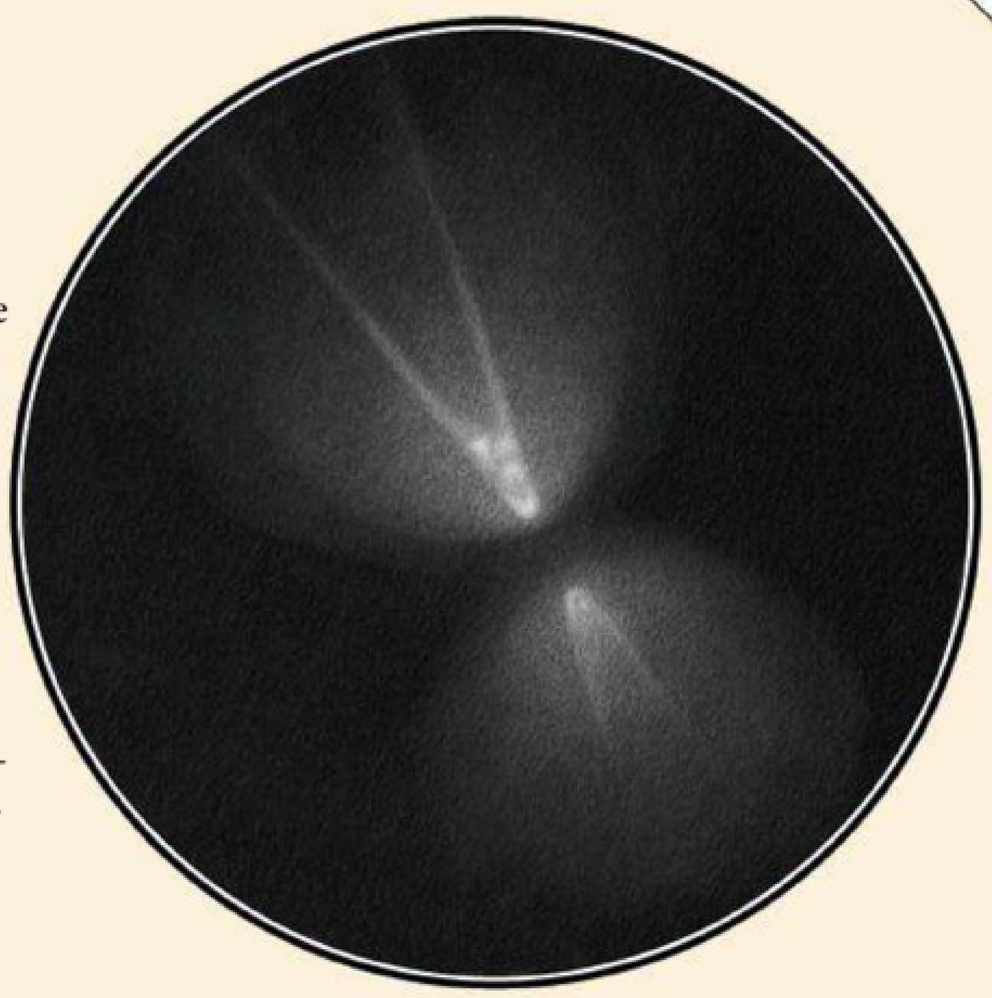
Location: Happy Jack, Arizona
Altitude: 7,667 feet (2,337 meters)
Aperture: 168 inches (4.3 meters)
Mount: Alt-azimuth
Dome size: 73 feet (22 meters) tall, 65 feet (20 meters) across

Visit Lowell Observatory: Monday, Wednesday, Friday, or Saturday 12 P.M.–9:30 P.M. or Tuesday, Thursday, or Sunday 12 P.M.–5 P.M. Mountain Standard Time. The $12 admission for adults and $6 admission for children covers both day and evening programs, including tours of the research facilities each day at 2 P.M. and the 42-minute film *Scanning the Skies: The Discovery Channel Telescope*.



Two large doors, different from a traditional dome's slit, slide open to give the Discovery Channel Telescope access to the darkening sky.

CRL 2688 Through amateur telescopes, the Egg Nebula (CRL 2688), is a small disk whose brightness changes when viewed through a variable polarizer. The DCT, however, showed much of the detail that we thought was reserved only for deep photographs. Two luminous yellow lobes diverged from a central gap. The northeastern one was bigger and brighter, containing lustrous clumps and exhibiting thin rays that extended from its edges; the southwestern lobe showed similar, but more subdued detail.



While the Egg Nebula (CRL 2688) looks like a small disk through an amateur telescope, the Discovery Channel Telescope showed the kind of detail normally reserved for long-exposure images.

M13 With a field of view of 6 arcminutes, the telescope did not allow us to see the entirety of the Hercules Cluster (M13). We could, however, look at the great globular cluster's core, where all the action is. At this scale, M13 took on the appearance of an extremely rich open cluster. More than a thousand stars peppered the field, all tiny, sharp points in the great seeing overhead. The brightest 50 or so of these stars were striking orange, while a number of the fainter members were blue. Gone was the familiar background haze of unresolved stars, as I got the sense that I was peering right through the globular. The star density fell off rapidly outside a 2-arcminute radius from the center.



The author's visit to the Discovery Channel Telescope changed his view of the universe.

Discovery in the future

Although you probably will not have the chance to view the night sky through the DCT, its results and images will make their way to you. The first scientific results came out in the October 2013 issue of *The Astrophysical Journal*, in which Lowell astronomers Dave Schleicher, Matthew Knight, and Stephen Levine reported their observations of Comet 10P/Tempel, which revealed the details of the comet's rotation. Discovery Communications is committed to reporting the scope's discoveries and bringing them to the wider world.

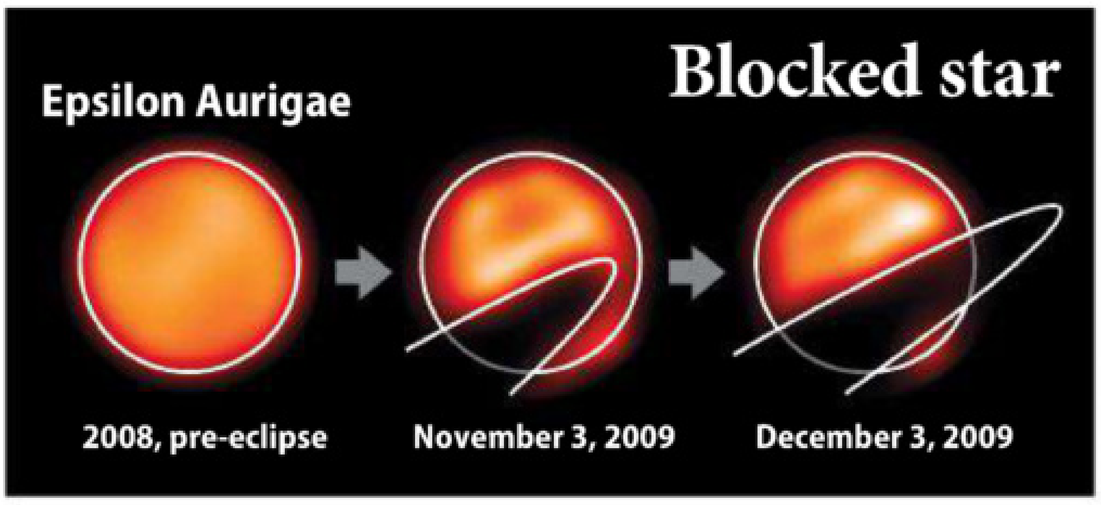
Our eight hours at the eyepiece had raced by after our first view of a daytime Moon. The observing session ended just after moonset, with the Milky Way arching overhead. Having reached new levels of "aperture fever" and with stunning images burned into our memory, we left with the desire to observe familiar objects more carefully, knowing what lurks within.

TO SEE MORE IMAGES OF TOM POLAKIS' TRIP TO THE DISCOVERY CHANNEL TELESCOPE, VISIT **www.Astronomy.com/toc.**

STELLAR ECLIPSE

Q: EVERY 27 YEARS, A TWO-YEAR ECLIPSE OF EPSILON AURIGAE OCCURS. DO SCIENTISTS KNOW WHAT CAUSES IT?

James McArdle, *Renton, Washington*



JOHN D. MONNIER, UNIVERSITY OF MICHIGAN

Astronomers think a hot young star enshrouded in a wide dust disk passes in front of Epsilon Aurigae every 27 years.

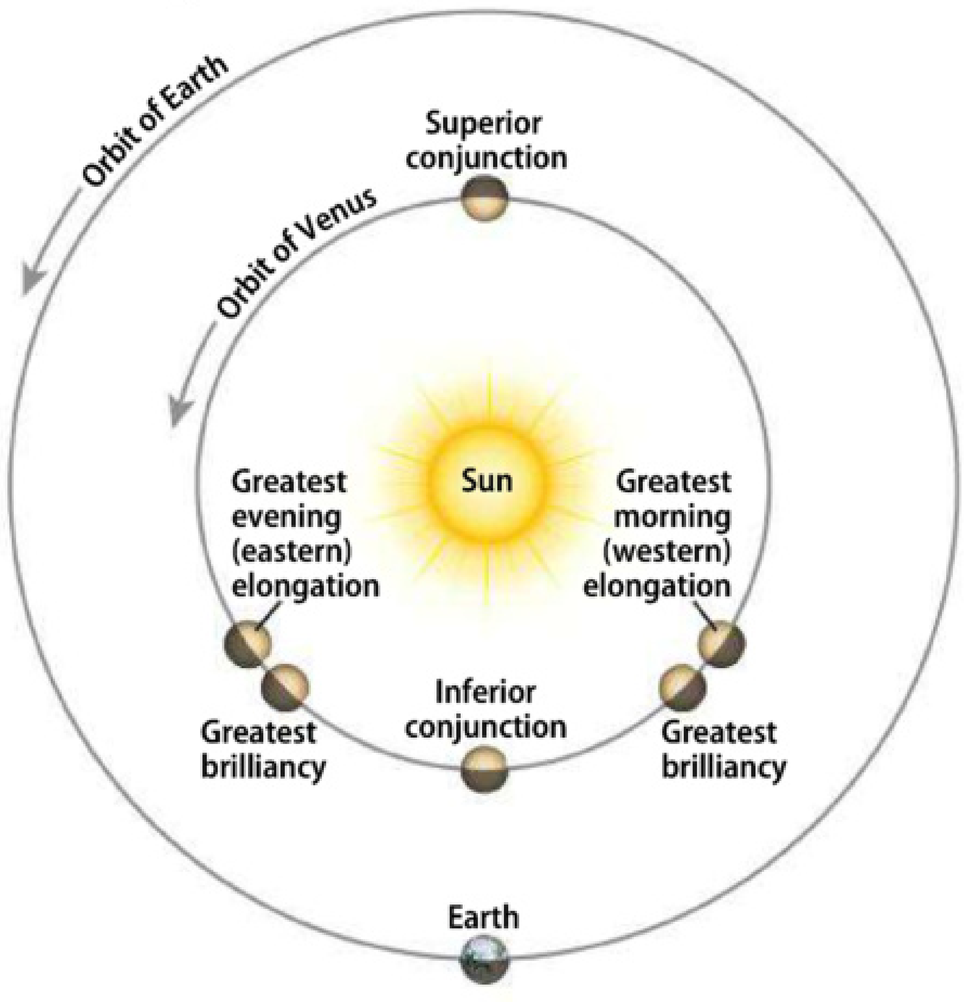
A: Yes, astronomers have confirmed that the eclipse's "invisible" cause is a cool, flattened disk of material encircling a central star that orbits the visible 7500-kelvin (13,000° Fahrenheit) type F supergiant star Epsilon Aurigae. This disk is similar to those surrounding T Tauri stars, a type of variable sun that is typically in an early stage of stellar evolution, and Beta Pictoris, which is progressively losing its protoplanetary disk. Scientists imaged Epsilon Aurigae during the 2009 to 2011 eclipse with the Center for High Angular Resolution Astronomy six-telescope interferometer array atop Mount Wilson in Southern California. The observation confirmed an earlier infrared result during the 1982 to 1984 eclipse, indicating that a 500 K (440° F) source is present in the binary system. Researchers expect that this relatively cool dust disk, some 0.6 astronomical unit thick (where 1 AU is the average Earth-Sun distance), will eclipse the visible star next in 2036 to 2038.

The fact that the eclipse lasts nearly two years means that the disk is at least 8 AU in diameter — filling all the space around its central star outward to nearly where the orbit of Jupiter in our solar system is. While scientists haven't directly observed the hidden central star, they think it might be a young and hot type B sun.

But there are still open questions about Epsilon Aurigae that astronomers are actively researching with the extensive observations made during the last eclipse, including: What is the disk made of? How long has it been there? And how long will it remain in the system?

Robert Stencel
University of Denver

Solar system geometries



The Sun-Earth-Venus geometry gives us many observing highlights, all illustrated in this diagram. *ASTRONOMY*: ROEN KELLY, AFTER HOLLEY Y. BAKICH

Q: THE CLOSER VENUS GETS TO EARTH AS IT ORBITS, AND THE LARGER IT GROWS, THE SKINNIER ITS CRESCENT PHASE. SO AT WHAT POINT IN ITS ORBIT DOES VENUS APPEAR BRIGHTEST?

David T. Wolf
San Carlos, California

A: Because Venus is closer to the Sun than Earth, it goes through a pattern of inferior conjunction (when it lies between the Sun and Earth), greatest western elongation (when we see it farthest from the Sun in the morning sky), superior conjunction (when it lies on the opposite side of the Sun from Earth), and greatest eastern elongation (when we see it farthest from the Sun in the evening sky).

The planet also reaches two points in its orbit when the Sun-Earth-Venus angle lets us see it at its brightest. These events, known as greatest brilliancy, occur when Venus lies at an elongation of 39°, approximately 36 days before and after inferior conjunction. These two points are where the illuminated fraction of Venus and its distance from Earth work together to maximize the amount of light we detect from our sister planet.

Michael E. Bakich
Senior Editor

Q: IF QUASARS ARE ACTIVE GALACTIC NUCLEI, THEN I WOULD EXPECT THAT THEY WOULD BE SPREAD RANDOMLY THROUGHOUT THE UNIVERSE. WHY ARE QUASARS INSTEAD OBSERVED AT FAR DISTANCES?

Marek Blas
Sydney

A: The simple answer: because luminous quasars are still visible from large distances, while fainter active galactic nuclei (AGNs) are not.

Quasars are the highest luminosity (more than 100 billion times that of the Sun) and most massive (more than 100 million solar masses) subset of AGNs. Their dimmer cousins are generally called Seyfert galaxies (with luminosities between 1 billion and 100 billion times that of the Sun, and masses between 1 million and 100 million solar masses).

A number of factors conspire to give the appearance that quasars are primarily at larger distances. First, because they are more luminous, we can detect them from farther away, while Seyfert galaxies are fainter and thus harder to see. Second, like the tallest people compared to those of average height, quasars are rare compared with their lower-luminosity counterparts. Third, the volume of space close to Earth is much smaller than that at large distances, so a single, uniformly distributed population would still appear to lie mostly far from us.

The combination of these factors leads us to see few quasars and many more Seyferts nearby and a gradual reversal as we look farther away and can no longer see the fainter sources. However, the reality is a bit more complex than this simple picture.

Quasars and other AGNs are distributed randomly in all directions over the sky but not in terms of distance. We usually measure distances in redshift, which tells us how much cosmic expansion has stretched light from a specific object; the more stretch, the farther away the galaxy is. The most distant AGNs known are around redshift 7, meaning the light has been traveling to reach us for 13 billion years. (The current age of the universe is roughly 13.8 billion years.) We think the first AGNs formed around redshifts of 7 to 10. At those distances, only the brightest — the quasars — are visible to us. The number of AGNs per unit of volume increases in regions of the universe that lie closer to us, redshifts of 3 to 5. This density peaks at a redshift of about 2 (when the universe was about 3.3 billion years old) and decreases at later times (closer to us). This means that AGNs are not distributed randomly throughout the universe.

We think that the supermassive black holes that power AGNs take a while to grow before "turning on" as active galaxies. They eventually reach a peak in energy output, and then they begin to run out of fuel as these black holes have either swallowed all the gas in their host galaxies or that material all turned into stars. Thus, the AGNs become fainter at later times and eventually stop being "active" galactic nuclei.

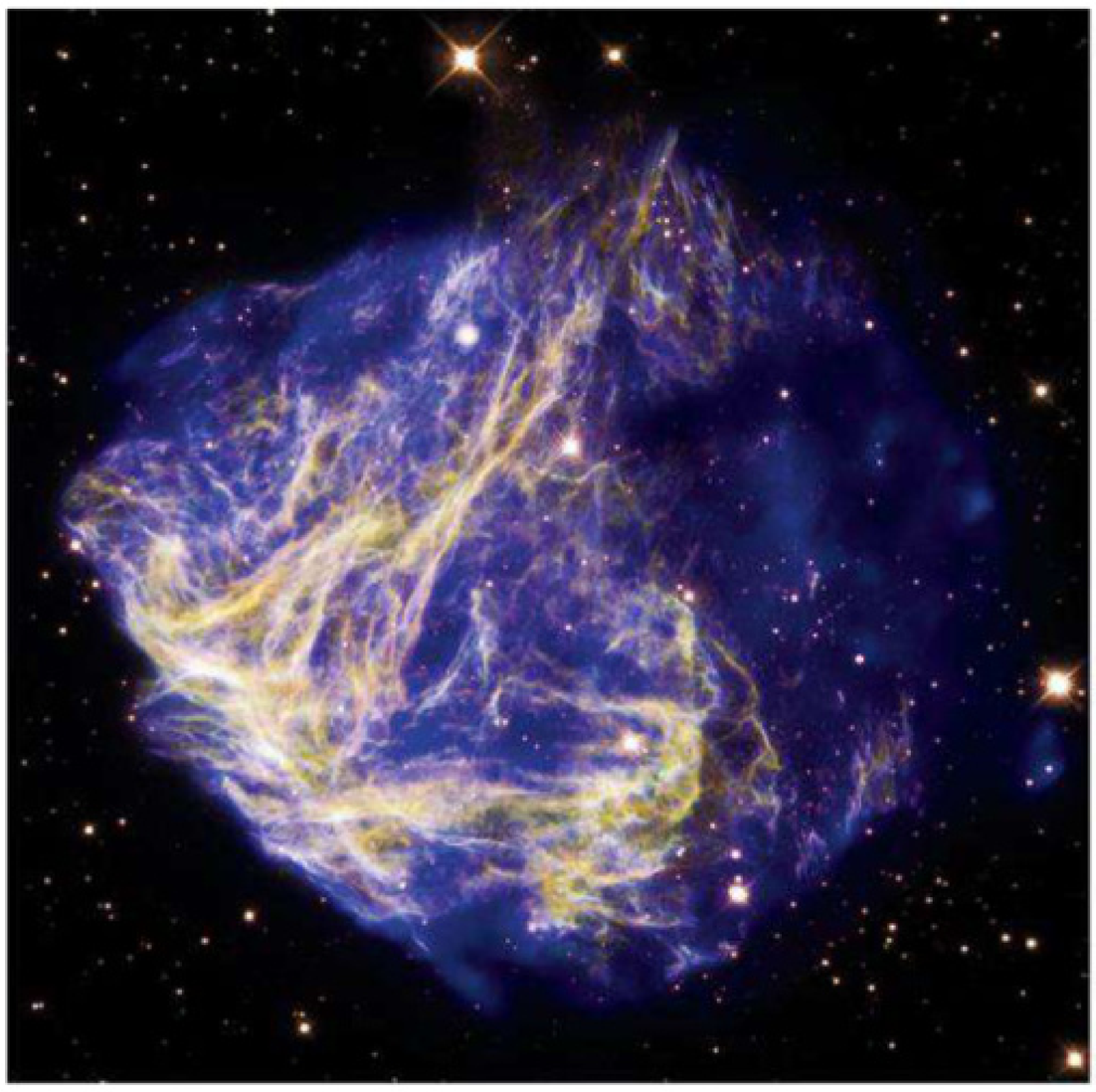
One more twist: Evidence suggests that the largest, most luminous AGNs (the quasars) grow the fastest and run out of fuel sooner than Seyfert galaxies. (This phenomenon is analogous to the evolution of stars, where the most massive burn their fuel fast [in millions of years] and blow up as supernovae, while smaller ones like our Sun are still middle-aged after billions of years.) We call this idea the "cosmic downsizing" of AGNs: Those that are active in later times are low-luminosity and low-mass ones. Perhaps the initial statement that quasars are mostly at large distances was not so far from the current "truth."

Belinda Wilkes
Smithsonian Astrophysical Observatory, Cambridge, Massachusetts

Q: WHERE DOES THE IRON IN THE SUN COME FROM?

Bob Schofield
Portland, Oregon

A: Observers commonly express the Sun's composition by the percentage of total number of atoms. Ignoring the solar core, where hydrogen fuses to helium, the Sun's outer layers consist of more than 91 percent hydrogen and more than 8 percent helium (all the former and most of the latter made within the first few minutes after the Big Bang). The rest of the chemical elements constitute just 0.15 percent or so of the number of atoms in the Sun.



X-RAY: NASA/CXC/PENN STATE/S. PARK, ET AL.; OPTICAL: NASA/STScI/UIUC/Y. H. CHU & R. WILLIAMS, ET AL.

Exploding stars called supernovae produce most of the universe's heavy elements, including iron. N49, imaged here, is the aftermath of a supernova whose light reached Earth some 5,000 years ago. The remnant lies in the Milky Way's neighboring galaxy, the Large Magellanic Cloud.

There is only one iron atom for every 31,600 of hydrogen. The Sun is not hot enough, even at its center, to make iron by the fusion of lighter elements. Instead, exploding stars, called supernovae, make all the iron strewn in the universe.

These explosions fall into two categories: In one, the core of a massive star suddenly collapses, while in the other, a Sun-like star's remnant core — a white dwarf — becomes overloaded beyond its carrying capacity after drawing mass from a companion. The temperatures in the resulting explosions are so high that all the elements heavier than hydrogen, including iron, are created through fusion and other nuclear processes and then ejected into interstellar space. (While stars eight times as massive as the Sun create iron at their cores during their lives, that fused material collapses and evolves into a neutron star or black hole.)

The Sun is 4.6 billion years old, but our galaxy is 8 billion years older. The interstellar clouds from which the Sun formed had plenty of time to incorporate the iron and other heavy elements from supernovae into the infant Sun and its planetary system. The solar chemical composition, including its iron content, is vital information that we use to test theories of how stars and our galaxy evolved.

Jim Kaler
University of Illinois, Urbana-Champaign

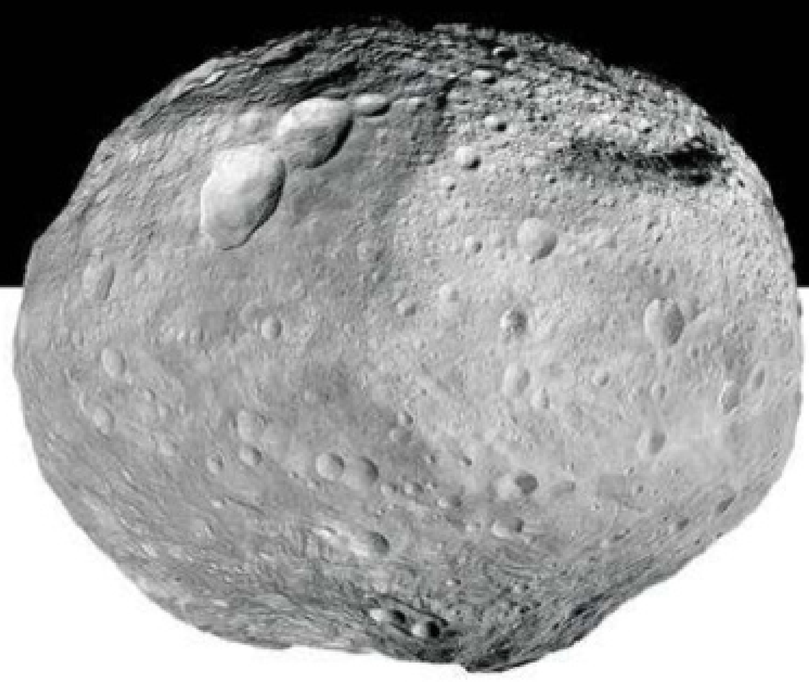
Send us your questions

Send your astronomy questions via email to **askastro@astronomy.com**, or write to Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

View **Ceres** and **Vesta** at their **best**

Take time this spring to track down the two brightest asteroids, which reach opposition and peak visibility within two days and 3° of each other.

by Richard Talcott

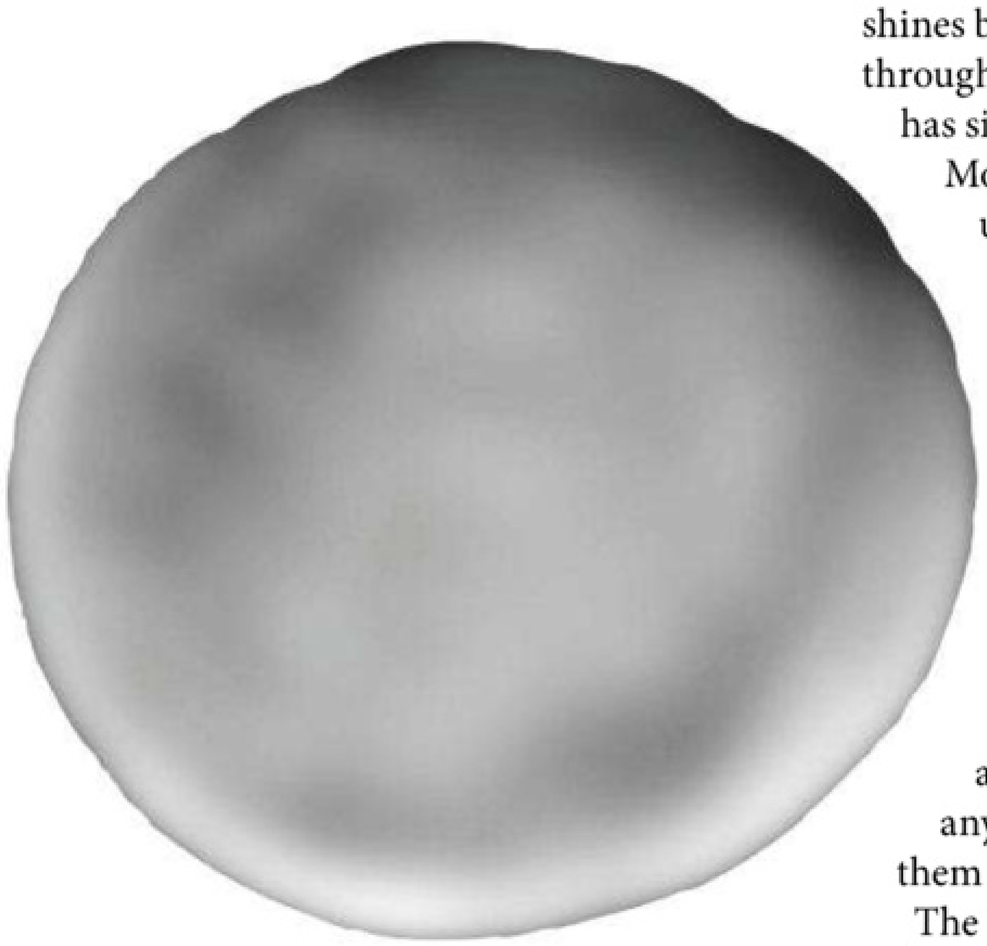


Through the eyes of NASA's Dawn spacecraft, the asteroid Vesta resolves into a patchwork of craters and a towering mountain at its south pole (bottom). NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA

When amateur astronomers look back on 2014, Virgo the Maiden will figure prominently in some of their most pleasant memories. The sprawling constellation hosts several spectacular events this year. At the top of the list are two sights guaranteed to thrill any observer. First, Mars shines brighter and appears larger through a telescope this spring than it has since late 2007. Second, the Full Moon passes completely into Earth's umbral shadow the night of April 14/15, creating the first total lunar eclipse in nearly 2½ years.

But another event, more difficult to view but arguably just as rewarding, takes place in Virgo this spring and summer. Ceres and Vesta — the two brightest and most massive asteroids in the main belt between Mars and Jupiter — appear closer to each other than at any time since astronomers discovered them more than 200 years ago.

The two objects move in tandem with each other throughout April and May, when they remain 2° to 3° apart and show up easily in the same binocular field. But this is just a prelude to the main event in early July, when the pair close to within a minuscule 0.17° — just one-third the apparent diameter of the Full Moon.



The sharpest views yet of Ceres have come from the Keck Observatory on Hawaii's Mauna Kea. The observations show this dwarf planet to be icy and spherical. NASA/JPL-CALTECH/C. DUMAS, ET AL.

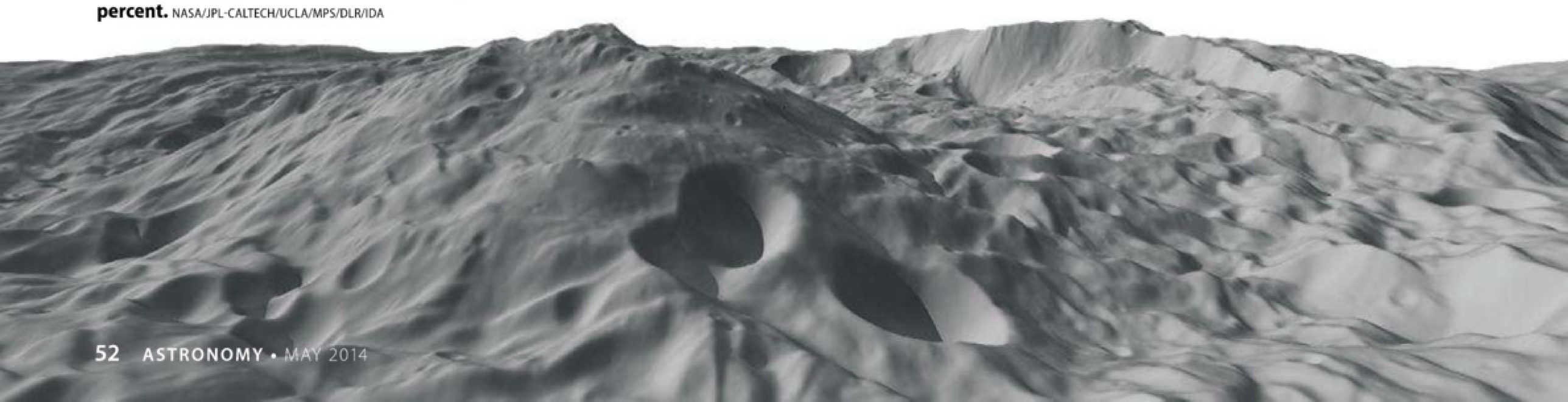
Vesta's rugged south polar region shows up in this view calculated from a shape model that removes the horizon's curvature. Imaging scientists exaggerated the vertical scale by 50 percent. NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA

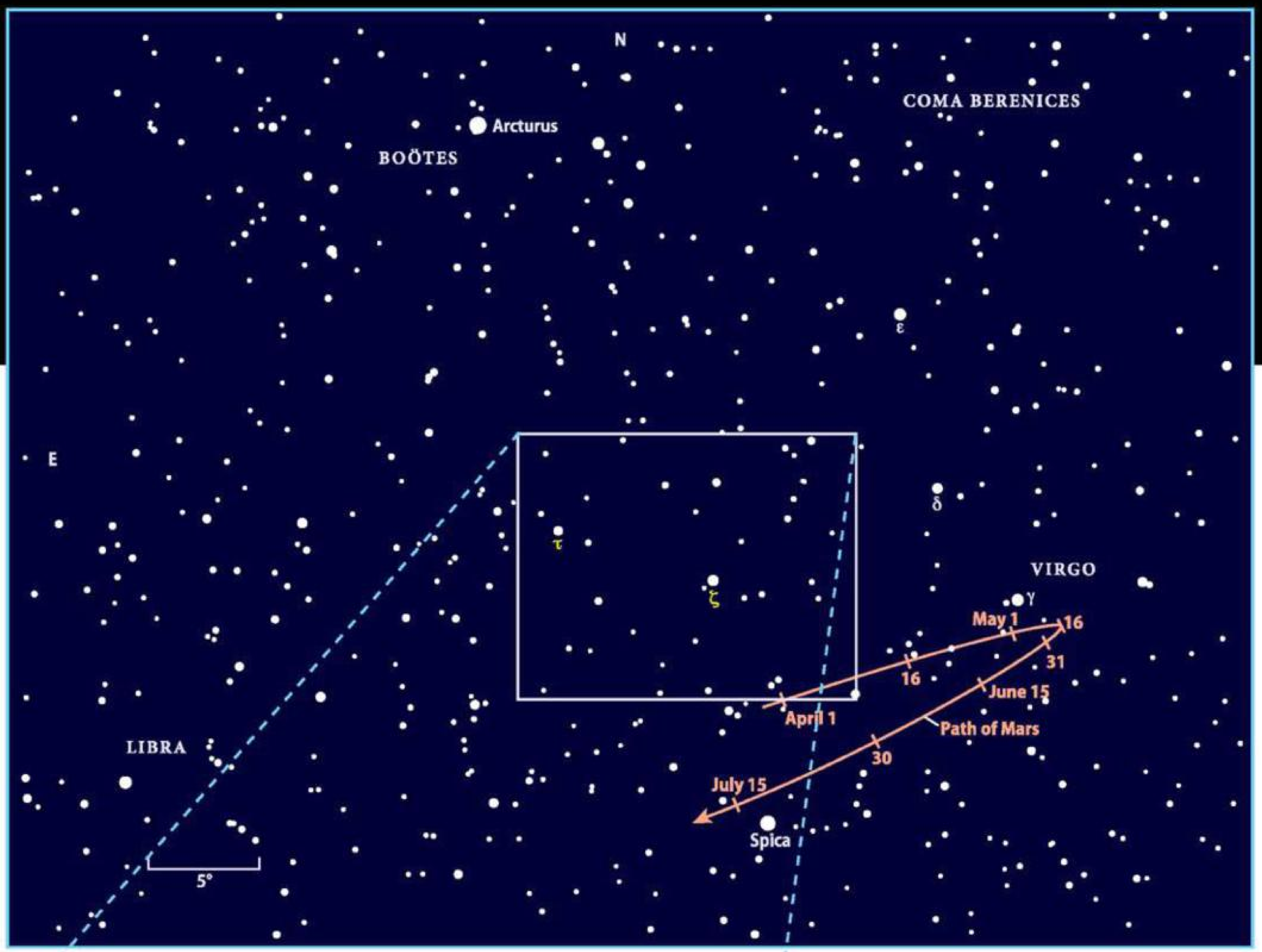
A shared past

Ceres and Vesta may be linked visually in 2014, but they also share a history. At the dawn of the 19th century, astronomers' inventory of the solar system's major bodies included just seven planets and 14 moons. This started to change on the evening of January 1, 1801, when Italian astronomer Giuseppe Piazzi turned the 3-inch telescope at Palermo Observatory to the sky. While plotting the precise positions of stars in western Taurus for a new catalog, he happened upon a faint "star" that had not appeared on previous charts.

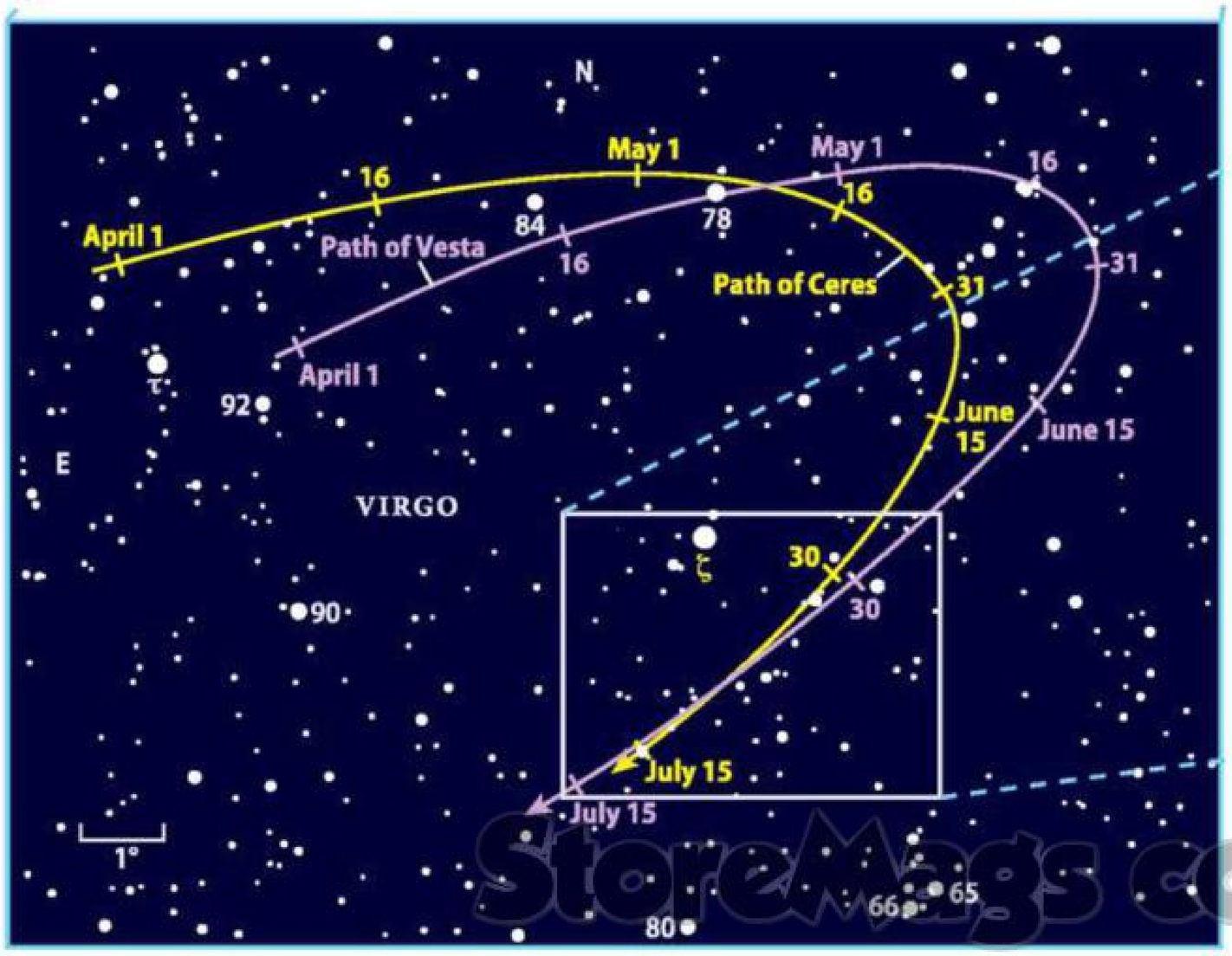
At the time, finding previously unknown objects while peering through high-quality optics was not unusual. But when Piazzi returned to the same field the following night, he noticed that the star had changed position. The movement continued on the next night, and the one after.

Piazzi knew that he had stumbled upon something special. An object that shifts





Asteroids Ceres and Vesta spend the spring and summer near each other in northern Virgo, roughly halfway between that constellation's brightest star, Spica, and Boötes' luminary, Arcturus. Ruddy Mars, which appears brighter than either star, also lies nearby. ALL ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

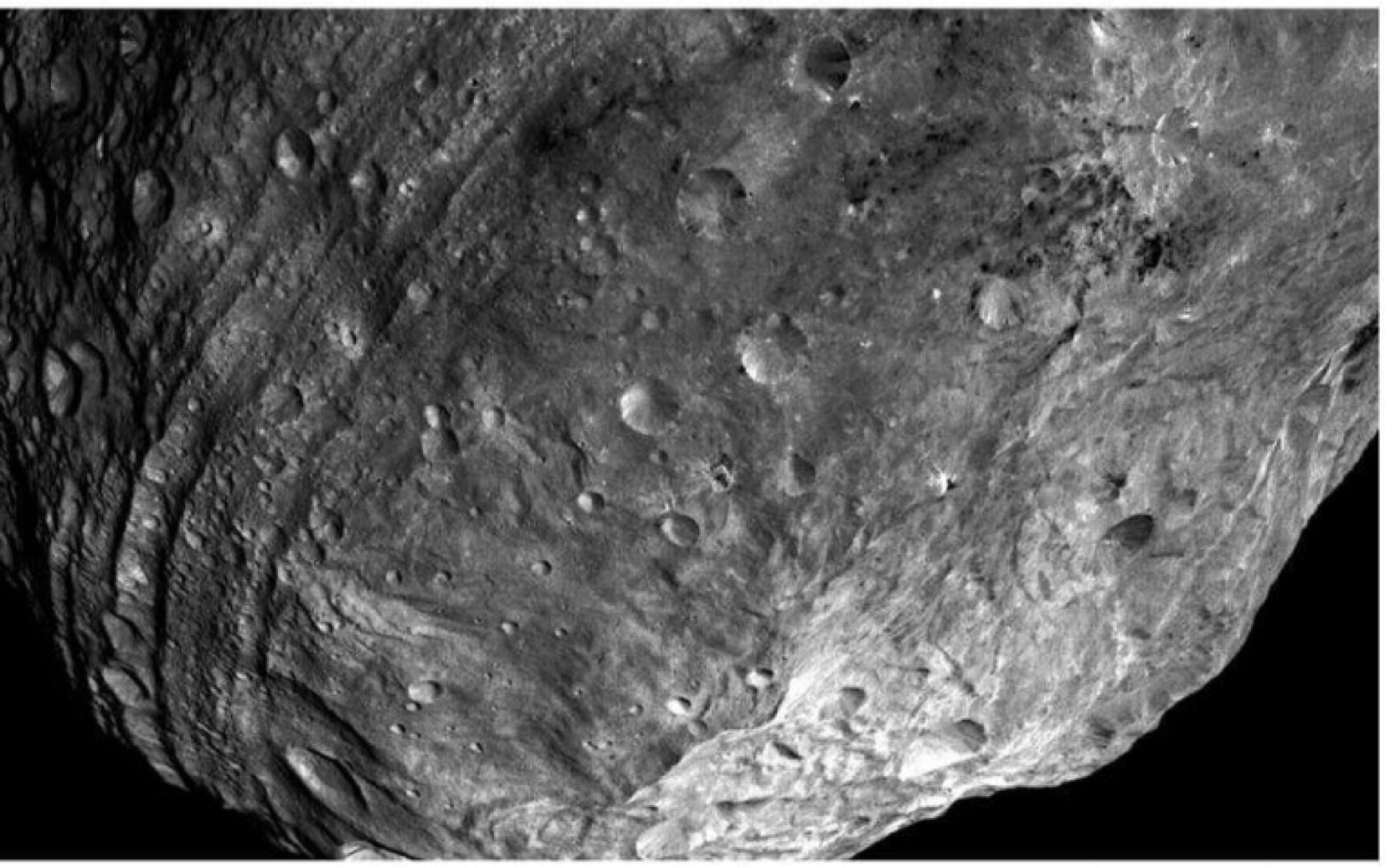


The brightest star close to Ceres and Vesta is 3rd-magnitude Zeta (ζ) Virginis. This chart shows stars to 9th magnitude, so identifying the two asteroids should be easy.



Ceres and Vesta pass within 0.17° of each other in early July, their closest approach since they were discovered in the early 1800s.

StarMags.com



The intriguing series of 6-mile-wide (10 kilometers) grooves near Vesta's equator (upper left) likely formed from the massive impact that created Rheasilvia Crater. NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA

position relative to background stars belongs to our solar system — the body's motion reflects its revolution around the Sun. At first, Piazzi thought the new object might be a comet, but the lack of any surrounding nebulosity gave him pause. Within a few weeks, he seriously considered the idea that this was a new planet.

By springtime, observations from Piazzi and other astronomers allowed orbital calculations that essentially confirmed this hypothesis. The discovery created a sensation. Not only was this the first new planet detected since 1781, when William Herschel spotted Uranus from his garden in Bath, England, but it also appeared to be the long-sought "missing planet" between the orbits of Mars and Jupiter.

For at least 200 years, scientists had noted the wide gap that separates these two worlds. Many believed that a substantial body existed in this void, and the new planet — named "Ceres" after the patron goddess of Sicily — seemed to fit the bill.

And then came Pallas

But there was a problem: Ceres seemed too small to be a full-fledged planet. Just a fraction the size of any other planet, it hardly seemed worthy of the name. German astronomer Heinrich Olbers further complicated matters in March 1802 when he discovered another smallish object lurking between Mars and Jupiter. Olbers dubbed the new body "Pallas."

But the idea that a full-sized planet might exist in the wide gap did not die. Olbers himself noticed the similarity in the orbits of Ceres and Pallas and conjectured that they might be two pieces of a larger planet that either had exploded or broken apart when a comet crashed into it.

Astronomers realized that the fragments of such an event would, for a time at least, follow orbits that would intersect both at the explosion's site and at a point on the opposite side of the Sun — near the constellations Virgo and Cetus. By searching in these regions, German astronomer Karl Harding discovered Juno just beyond Cetus' borders in September 1804 while Olbers spotted Vesta among Virgo's stars in March 1807.

Richard Talcott *is an* Astronomy *senior editor and author of* Teach Yourself Visually Astronomy *(Wiley Publishing, 2008).*

At William Herschel's suggestion, the objects became known as asteroids (meaning "starlike") because they appear as points of light. Although it was nearly 40 years before observers found a fifth one, they have since discovered several hundred thousand. Astronomers today understand that they are not pieces of a major planet's demise, but remnants from the solar system's formation. They never had a chance to grow into a single large object because Jupiter's gravity kept the asteroid belt stirred up.

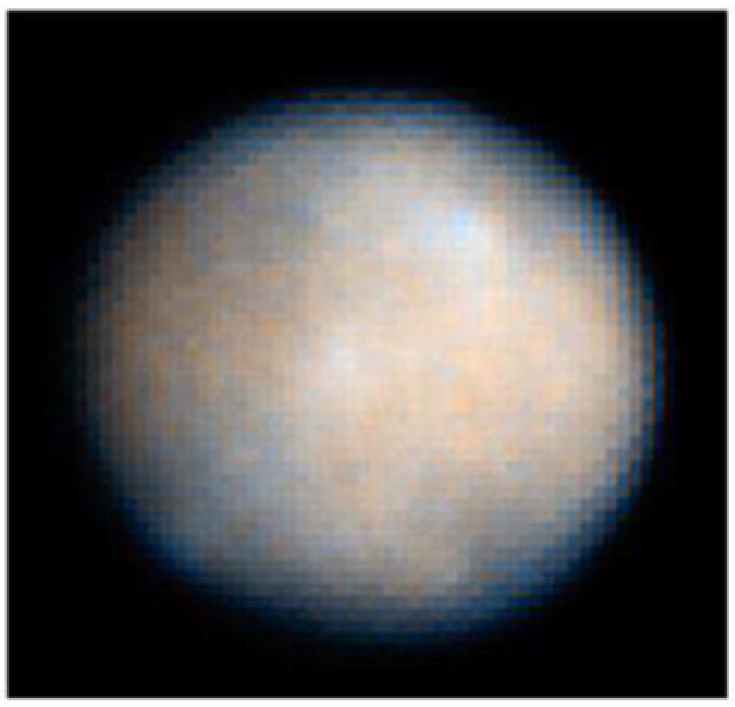
Dancing with the Maiden

Now, a little over two centuries since their discoveries, Ceres and Vesta return to the scene of their purported birth in Virgo. Thanks to high-quality optics and accurate finder charts, amateur astronomers will have a much easier time finding the two asteroids than Piazzi and Olbers did.

You can start looking for the pair in early April. (Since most *Astronomy* subscribers receive their copies a month earlier than the issue date, we decided to give you a few extra weeks to observe.) On the evening of April 1, Ceres shines at magnitude 7.1 and stands 2.5° east-northeast of magnitude 5.9 Vesta. The latter glows brightly enough to see with naked eyes from under a dark sky, while Ceres shows up easily through binoculars from the suburbs. Both objects will fit comfortably in a single binocular field of view.

Use the charts on p. 53 to get to the right area. Three bright objects will guide you to the spot. The spring sky's brightest star, magnitude 0.0 Arcturus in Boötes, resides roughly 15° north of the asteroids; Virgo's brightest star, magnitude 1.0 Spica, lies a similar distance south. (A closed fist held at arm's length spans about 10°.)

But an even brighter object, Mars, lies within Virgo's borders this spring and



The Hubble Space Telescope reveals Ceres as a mottled object with light and dark areas, which scientists interpret as either impact features or variations in surface material. NASA/ESA/STScI



Hubble shows a bit more detail on Vesta because, although the asteroid is just 55 percent of Ceres' size, it is closer to Earth. The indentation at bottom right is the giant Rheasilvia impact crater. NASA/ESA/STScI

summer. It is a moving target, however, so we've plotted its position on the wide-field map at the top of p. 53 every 15 days. The Red Planet's distinctive glow will help you pinpoint Arcturus, Spica, and the fainter suns on the map, which shows all stars visible to naked eyes from a dark site.

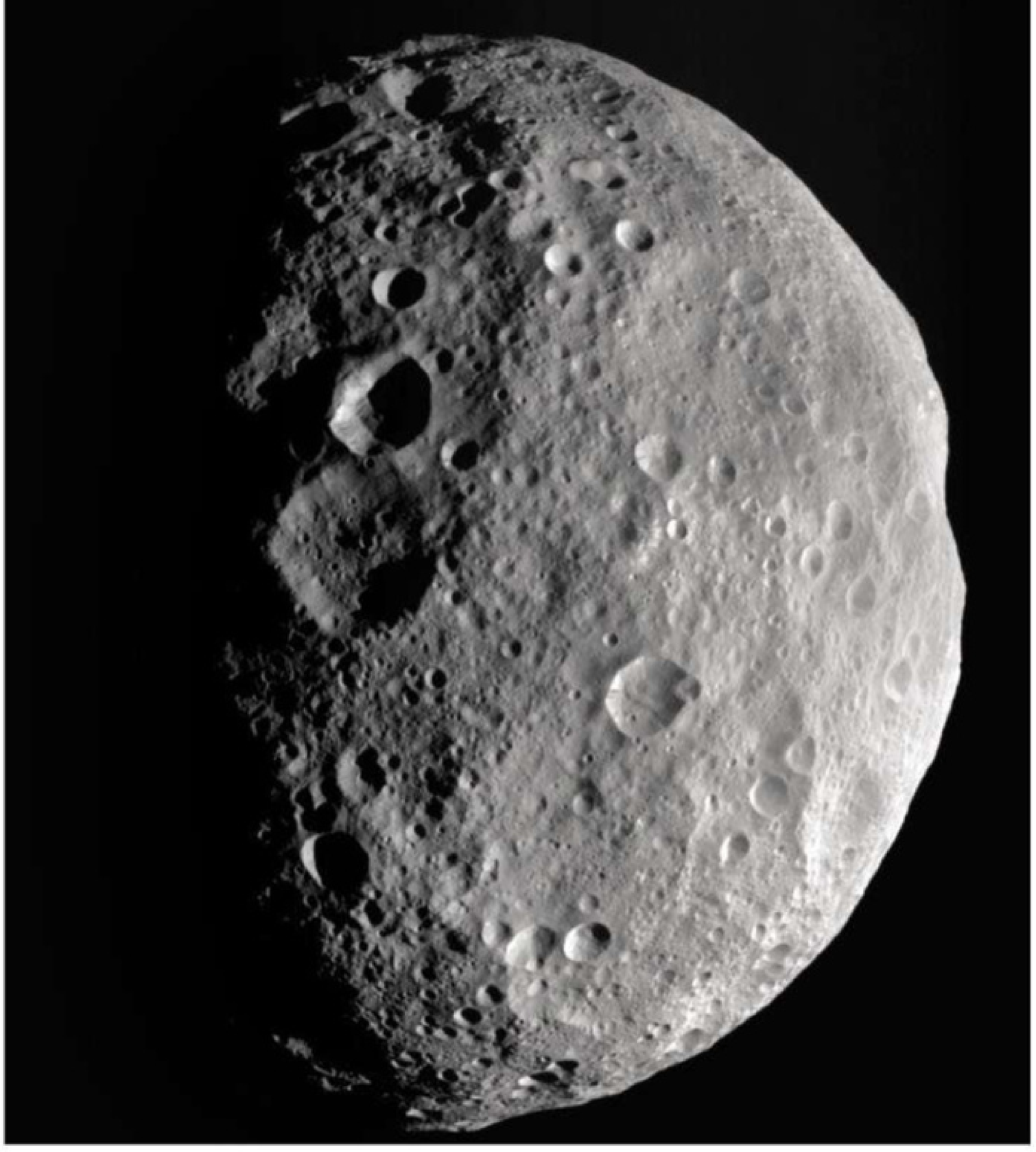
Once you've found the bright trio, narrow your focus to the region immediately surrounding the asteroids. The key star here is 3rd-magnitude Zeta (ζ) Virginis, which lies slightly below center on the close-up chart at the lower left of p. 53. Ceres and Vesta appear to loop around Zeta from April to July. This map shows stars down to magnitude 9.0, which is significantly fainter than either asteroid.

You should be able to identify Ceres and Vesta simply by comparing the asteroids' plotted positions to the locations of the background stars. If you can't distinguish the solar system wanderers from the stellar backdrop, use the technique Piazzi and Olbers employed. Plot the objects you see through your telescope near each object's position, and then return to the same field a night or two later. The "stars" that changed position are actually the asteroids.

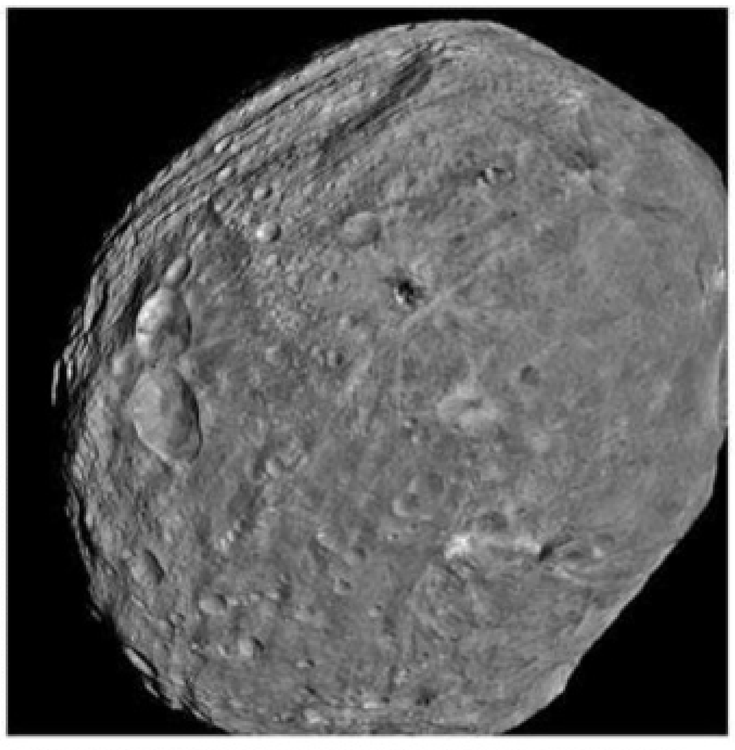
A historic approach

Ceres and Vesta shine brightest when they lie opposite the Sun in our sky in mid-April. Vesta shines at magnitude 5.7 when it reaches opposition April 13, while Ceres peaks at magnitude 7.0 two days later. Their similar paths and speeds keep them 2.5° apart throughout April, although their orientation changes so that Ceres lies due east of its neighbor on the month's final night.

Although this east-west alignment persists through May and June, the separation between Ceres and Vesta tightens considerably. The 2.5° gap on May 15 dwindles to 2.0° on June 1, 1.3° on June 15, and 0.4° on June 30. On June's final night, Vesta glows at magnitude 7.0 and Ceres at magnitude 8.4. Both are still within range of binoculars, though a telescope allows steadier and more leisurely views.



NASA's Dawn spacecraft captured this view as it was leaving Vesta and looking down on the asteroid's north pole. Dawn will reach Ceres in March 2015. NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA



NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA

Although Vesta is more rocky than icy, the three contiguous impact craters on the left side of this image give the distinct impression of a snowman.

This narrowing gap is just a warm-up for what happens during July's first week. On the North American evenings of July 4 and 5, the two approach within 0.17° (10′) — one-third the Full Moon's diameter. Vesta passes due south of Ceres at 5 A.M. EDT July 6, unfortunately after the pair has set. The two separate slowly thereafter, though they remain within 0.5° until July 11.

Despite their proximity in our sky, the two are in no danger of colliding. At the time of their closest approach, Ceres lies some 53 million miles (85 million kilometers) farther from Earth than Vesta.

You wouldn't know it by looking through your telescope, but another intriguing object lies in the same field as the two asteroids. NASA's Dawn spacecraft explored Vesta up close between July 2011 and September 2012. The probe revealed a cratered world 326 miles (525km) across that is covered largely with basaltic rock but also shows strong evidence of water ice at and beneath the surface.

Dawn is now on its way to Ceres, where it will arrive in March 2015. Much larger than its sibling, Ceres measures some 590 miles (950km) wide, and its self-gravity has pulled it into a spherical shape, earning it the designation of "dwarf planet" from the International Astronomical Union. Scientists expect Ceres to be much wetter than Vesta. Observations with the Herschel Space Observatory recently detected a thin water-vapor atmosphere around Ceres, and the world's low density argues that it has a thick mantle of water ice. For more on Dawn's mission to Vesta and Ceres, see "Exploring the biggest asteroids" in the March 2014 issue.

Like the Dawn spacecraft, however, those features remain hidden to earthbound observers. Still, the current proximity of Ceres and Vesta in the sky makes it easy to travel to these worlds in our imaginations and savor their historic close approach that allows us to view them simultaneously.

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24 gems near the North Celestial Pole

Point your telescope northward any clear night, and you'll see some of the best star clusters, nebulae, and galaxies in the sky.

by Michael E. Bakich



DANIEL B. PHILLIPS

The Iris Nebula (NGC 7023) lies in the constellation Cepheus the King. All reflection nebulae are blue, but the Iris is intensely so. Small particles within the nebula scatter and reflect light with a predominantly blue hue in much the same way that air molecules scatter mainly blue light throughout our daytime sky.

Most observing lists covering large swaths of sky are date specific. That is, they apply to a particular month or season. This list is different, as it highlights the region of sky near the North Celestial Pole, which is chock-full of deep-sky objects for all telescope sizes. If you observe from north of latitude 25° north, all of the objects featured are circumpolar. That means they never set at your location.

I've grouped these 24 treats by the five constellations that contain them. Within each group, you'll find the objects listed in order of their right ascension, meaning western ones come first. Galaxies, star clusters, double stars, and a variety of nebulae will whet your appetite. Just remember: When you head out to observe them, take your time. It's not like they're going to set.

Fit for a King

Our first six objects lie in the constellation Cepheus, and number one sits unassumingly near the King's head. Despite its low overall magnitude, planetary nebula **NGC 40**, also called the Bow-Tie Nebula, makes a fine target through telescopes because its surface brightness is high. The Bow-Tie sits 5.5° south-southeast of magnitude 3.2 Gamma (γ) Cephei.

A 4-inch telescope at a dark site will reveal an oval disk about one-third longer than it is wide with a magnitude 11.6 central star. Through a 10-inch scope, NGC 40's disk shows several bright knots toward the southeast and northwest. Increase the magnification past 200x (if the seeing permits), and look for a dark cavity between the shell and the central star.

Next up is one of the sky's most northerly deep-sky targets. Open cluster **NGC 188** lies less than 5° from Polaris (Alpha [α] Ursae Minoris). Through an 8-inch telescope at 100x, you'll see about 50 magnitude 13 and fainter stars. A 12-inch scope at a dark site will allow you to count twice that number of suns. As you focus on the bright points, dark lanes seem to run through the cluster, adding to the visual appeal.

The first galaxy on our list is the spiral **NGC 6951**. You'll find it 5.7° northwest of magnitude 2.5 Alderamin (Alpha Cep). You'll need at least a 10-inch scope to pick out any detail.

With magnifications greater than 250x, try to spot the thin spiral arm toward the southeast. Also look for the magnitude 12.2 star GSC 4258:1945 superposed on the galaxy's western edge.

For our next target, imagine a cloud of countless dust particles that together function as a special type of cosmic mirror called a reflection nebula. This particular one, cataloged as **NGC 7023**, reminds observers more of a flower, though, and thus has earned the nickname the Iris Nebula.

You'll find this object 3.4° southwest of magnitude 3.2 Alfirk (Beta [β] Cep). Through a 10-inch telescope, the Iris Nebula appears as a uniformly bright circular haze about 1' across surrounding a 7th-magnitude central star. Look closely to see a small detached portion of the nebula just to the south.

Next, we'll visit star cluster **NGC 7129**, which also includes a star-forming region containing emission and reflection nebulosity. This jumble explains the object's common name — the Small Cluster Nebula. The three nebulous regions within this area are IC 5132, IC 5133, and IC 5134.

Michael E. Bakich *is a senior editor of* Astronomy.



Spiral galaxy NGC 2403 floats through space 8 million light-years away in the constellation Camelopardalis the Giraffe. It belongs to the M81 Group of galaxies, a collection of more than 30 star cities. NGC 2403 measures approximately 50,000 light-years across. It glows at magnitude 8.5 and has an apparent diameter of 23' along its major axis, which is 74 percent as large as the Full Moon. ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA

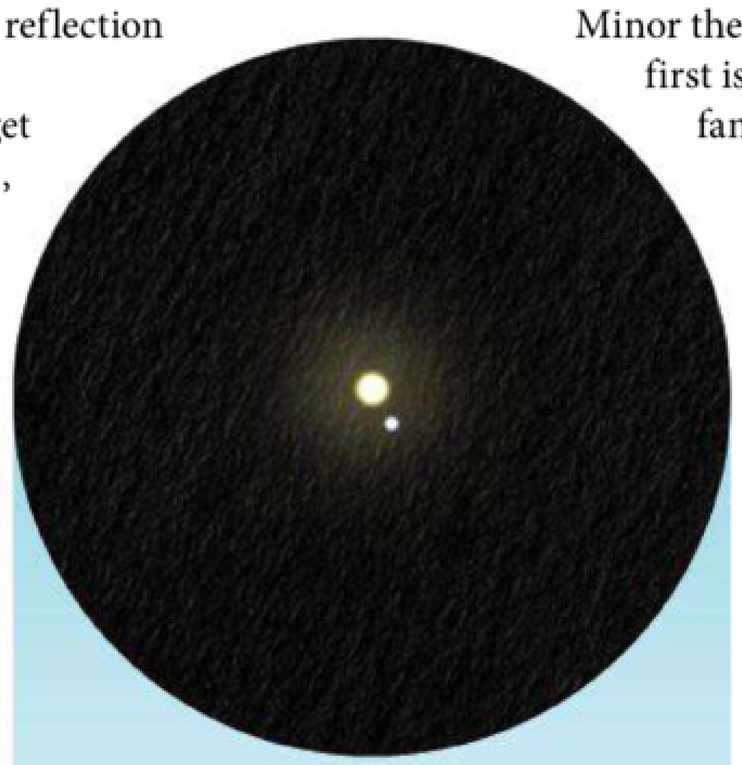
You'll find NGC 7129 2.6° northwest of magnitude 4.4 Kurhah (Xi [ξ] Cep). A 6-inch telescope will reveal the cluster, a rather poor collection of a dozen or so stars. To see the nebulae, however, you'll need to step up to at least a 10-inch scope. Most of the nebulosity is of the reflection type, so no filter helps.

To find our last target in Cepheus, **NGC 7142**, simply move 0.4° southeast of the previous object. In fact, I'd be surprised if you didn't sweep it up when you found NGC 7129.

This nice open cluster presents an even distribution of similarly bright stars. Most shine at magnitude 12, but a few 10th-magnitude gems pepper the group. Through a 6-inch telescope, three dozen stars pop into view. A 10-inch scope will reveal 50 members.

The Little Bear's lineup

Our next three objects float through Ursa Minor the Little Bear. And the first is the night sky's most famous star.



Although not apparent to the naked eye, Polaris actually is a binary star, as this sketch shows. JEREMY PEREZ

In 1780, English astronomer William Herschel discovered that **Polaris** was a binary star. Although the yellow primary outshines the blue secondary by more than 650 times, a 3-inch telescope at 100x easily will show you Polaris B.

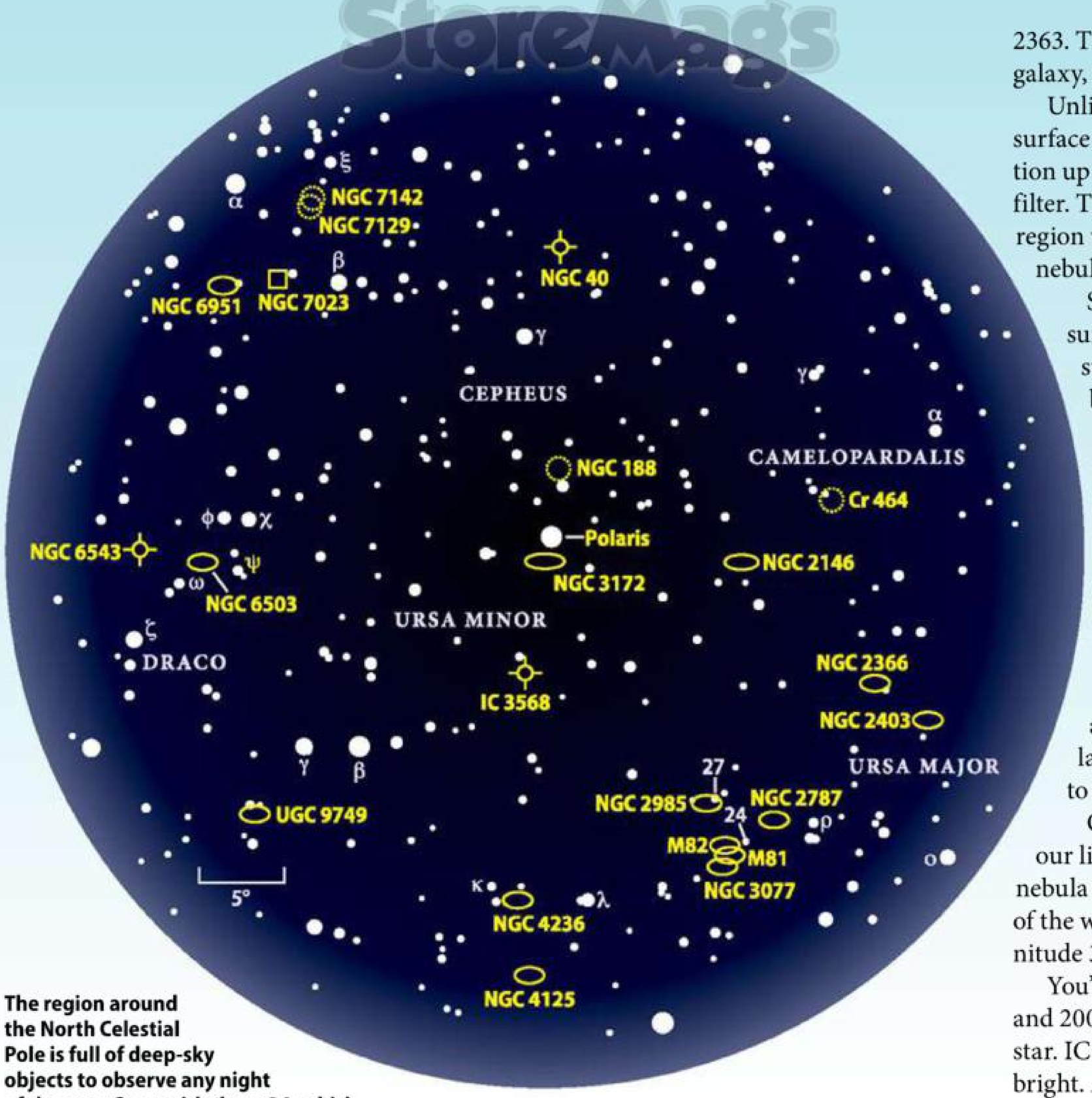
The next Ursa Minor deep-sky object is a tough catch: spiral galaxy **NGC 3172**. Because it glows dimly at magnitude 13.6 (and some estimates put it fainter than magnitude 14), you'll need a 12-inch scope and a really dark sky to spot it.

NGC 3172 is the closest NGC object to the North Celestial Pole — only 0.9° from that heavenly marker. Because of its extreme northern position, observers have dubbed NGC 3172 Polarissima Borealis. Visually, this object is a faint oval haze about 0.5' across with a slightly brighter center.

Our final target in the Little Bear lies in the southernmost part of the northernmost constellation. Magnitude 10.9 **UGC 9749** — also known as the Ursa Minor Dwarf — is a dwarf elliptical galaxy that lies 4.7° south-southwest of magnitude 3.0 Pherkad (Gamma UMi).

Use at least an 11-inch telescope, but don't crank the power up. In fact, you'll want to use the lowest-power, widest-field eyepiece you own. That's because UGC 9749 covers more area than the Full Moon

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The region around the North Celestial Pole is full of deep-sky objects to observe any night of the year. Start with these 24, which include 14 galaxies, four open clusters, three planetary nebulae, two double stars, and a reflection nebula. *ASTRONOMY*: ROEN KELLY

(which spans about ½°). The best approach for viewing this object is to disengage your telescope's drive and slowly sweep the Dwarf's region of sky. What you're looking for is an ever so slight increase in the background glow of your eyepiece's field of view.

Gravitate to the Giraffe

Now head to the ultra-faint constellation Camelopardalis the Giraffe for the next five sky wonders. The first is open cluster **Collinder 464** (Cr 464), a fine small-telescope target. You'll spot it roughly 7° north-northeast of magnitude 4.3 Alpha Camelopardalis.

Cr 464 spans a whopping 2°. The stars appear scattered, with the eastern and western sides sharply divided. The west section contains the most brilliant stars, with five brighter than magnitude 6.5. The five brightest stars in the east half range from magnitude 6.2 to 7.3. Binoculars will reveal the cluster, but I prefer a telescope with a magnification between 25x and 50x to really plumb Cr 464's depths.

Also within the Giraffe's boundaries is spiral galaxy **NGC 2146**, commonly known as the Dusty Hand Galaxy. The name comes from images that show a system of three dust lanes, which may be spiral arms. Finding it without a go-to drive isn't easy because of the lack of bright stars in the area. Look 11.6° northeast of magnitude 4.6 Gamma Cam. NGC 2146 displays a broad central region. Telescopes with apertures larger than 10 inches will show some mottling (alternating small bright and dark patches) close to the core and a dark, subtle lane near the southwestern edge.

Our next target is the faint irregular galaxy **NGC 2366**, another object with a low surface brightness. It lies 10.6° north-northwest of magnitude 3.4 Muscida (Omicron [o] Ursae Majoris). You'll need at least a 12-inch scope under a dark sky to see anything more than a dull glow. What you can see through smaller scopes is a cloud of ionized hydrogen, called an HII region, that lies off the galaxy's southwestern edge. You may see this feature cataloged as NGC 2363. That's an error (NGC 2363 is a nearby galaxy, and the HII region is Markarian 71).

Unlike the galaxy, the nebula has a high surface brightness. Crank the magnification up to 200x, and insert an Oxygen-III filter. The galaxy will disappear, but the HII region will remain bright. Look for the nebula's bright center.

Speaking of brilliance, despite being surrounded by Camelopardalis' faint stars, **NGC 2403** is one of the sky's brightest galaxies. It's large, however, so that brightness spreads along an axis 74 percent as large as that of the Full Moon. You'll find this galaxy 7.7° northwest of Muscida.

Small telescopes will show an indistinct haze roughly twice as long as it is wide, with a bright central region. Through a 12-inch scope, you'll begin to see the galaxy's spiral arms, but you'll need a larger instrument to trace them back to the nucleus.

Our next object, and the last one on our list in Camelopardalis, is planetary nebula **IC 3568**. To find it, look 40 percent of the way along a line from Polaris to magnitude 3.9 Kappa (κ) Draconis.

You'll need at least a 10-inch telescope and 200x to see the 13th-magnitude central star. IC 3568's tiny inner core appears bright. A slightly fainter shell surrounds it. You'll also spot a 12th-magnitude star just 15" to the west. Whatever scope you choose, be sure to use as high a magnification as conditions will allow.

Bear with me

Ursa Major the Great Bear contains myriad deep-sky objects, but I've selected five that lie near the pole. The first, spiral galaxy **NGC 2787**, is a bit of an odd duck. To find it, look 2.2° northeast of magnitude 4.8 Rho (ρ) UMa.

When I first viewed NGC 2787 through a large scope, I thought it might be a barred spiral. Astronomers, however, put it in a different class — barred lenticular (between a spiral and an elliptical). You'll see the bar. But don't let it puzzle you: Its long axis tilts a bit to the overall major axis of NGC 2787. The central region appears much brighter than the outer areas, yet details are scant.

You'll find our next target, spiral galaxy **NGC 2985**, in the Great Bear's northern part. It lies 0.6° east of the magnitude 5.2 star 27 UMa. The slightly oval shape is easy to spot at magnifications above 150x. Through a 10-inch or larger telescope, you'll

see the wide, faint outer halo. Done? Look for the magnitude 11.8 spiral galaxy NGC 3027, which lies 0.4° east of NGC 2985.

In the northwest section of Ursa Major sits **M81**, one of the sky's brightest galaxies. You'll find it 2° east-southeast of the magnitude 4.6 star 24 UMa. Astronomers call M81 Bode's Galaxy because German astronomer Johann Elert Bode discovered it in 1774.

Through an 8-inch scope, you'll see a large, bright central region surrounding the much brighter core. Through a 12-inch instrument, you can detect how the spiral arms wind tightly around the core; the easternmost appears brighter.

Point your telescope 37' due north of M81, and you might think you're seeing a galaxy explode. Not exactly. What you've found is **M82**, the classic example of a starburst galaxy.

Amateur astronomers call M82 the Cigar Galaxy because of its appearance through a small scope. It measures four times as long as wide. The galaxy's brightest part lies east of center. Farther east, a dark lane cuts diagonally across M82.

Our final Ursa Major target, irregular galaxy **NGC 3077**, lies 0.8° east-southeast of M81 and 1.1° southeast of M82. If, therefore, your telescope/eyepiece combination gives a bit more than a 1° field of view, you'll see all three galaxies at once.

This galaxy has a wide, bright nucleus. It's an oval with faint outer layers you'll have no trouble seeing.

The Dragon's delights

I still have five objects to describe, and they just so happen to lie in Draco the Dragon. To find elliptical galaxy **NGC 4125**, move 5.5° southeast from magnitude 3.8 Lambda (λ) Draconis.

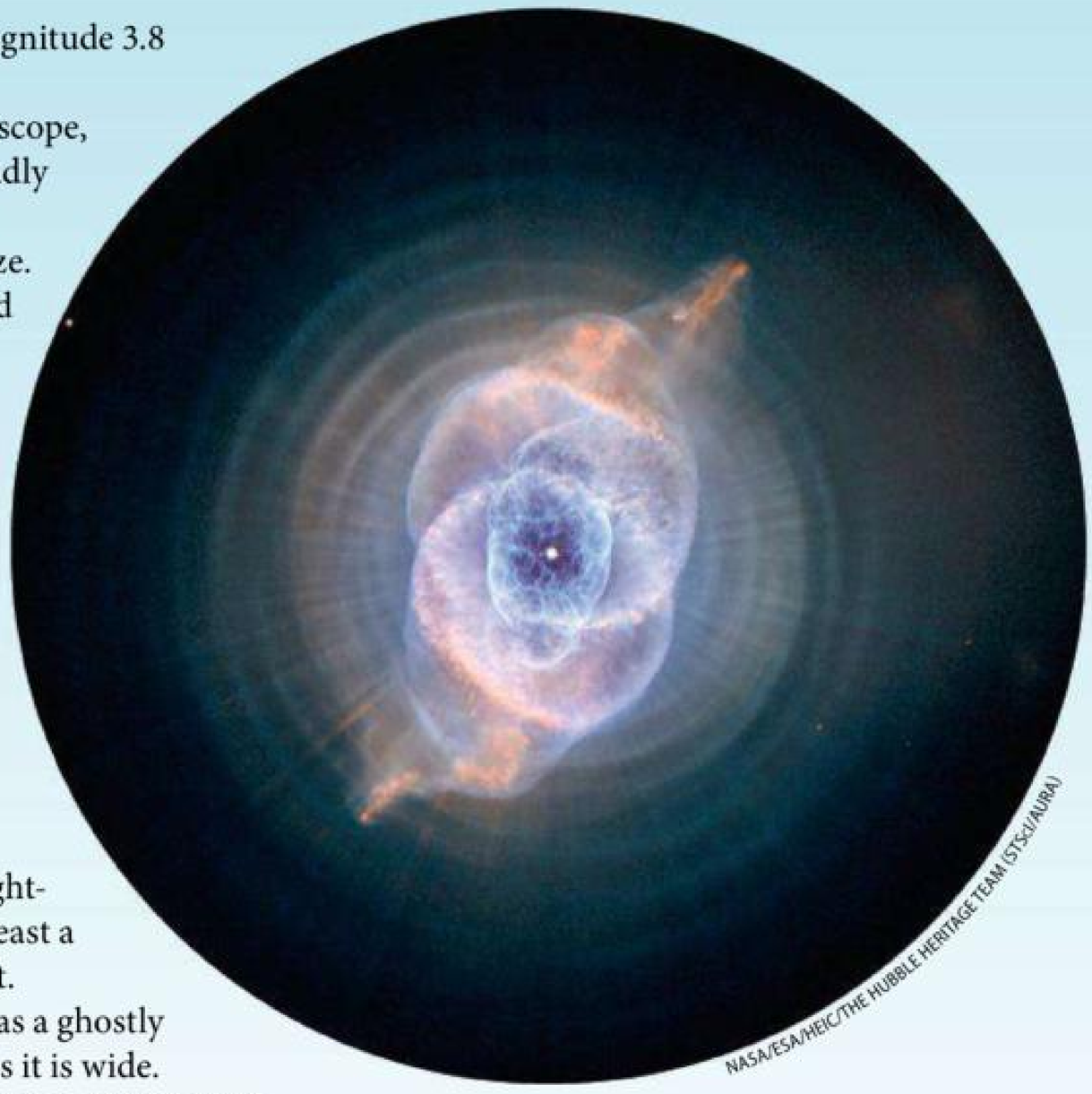
Through an 8-inch scope, you'll see a bright, broadly concentrated oval core with a surrounding haze. Larger apertures extend the length of the galaxy, and some observers have noted a nearly stellar nucleus.

Our second object in Draco lies 1.5° west of magnitude 3.9 Kappa Dra. Although the galaxy **NGC 4236**'s listed magnitude of 9.6 is bright, it's so huge that it has a low surface brightness, so you'll need at least a 10-inch scope to view it.

NGC 4236 appears as a ghostly mist six times as long as it is wide. Larger telescopes will reveal a number of faint knots that are star-forming regions similar to our galaxy's Orion Nebula (M42). Through a 14-inch telescope, look for the brightest of these HII regions at the south end of the spindle.

The next treat, **Psi (ψ) Draconis**, is only the second double star on this list, and you'll have no trouble splitting it. The primary is white, and the secondary is nearly so with just a trace of yellow. Psi Dra tops an isosceles triangle with Chi (χ) and Phi (ϕ) Dra forming the base. Psi lies roughly 3° from each of these stars.

Our fourth Draco target, **NGC 6503** — sometimes called the Lost in Space Galaxy — is a bright spiral you can spot easily through a 4-inch telescope. Find this galaxy by starting at magnitude 4.8 Omega (ω) Dra and moving 1.8° northeast. NGC 6503 displays a broadly concentrated region offset to the north of center, with surface mottling becoming apparent through a 16-inch scope.



A Hubble Space Telescope image reveals the Cat's Eye Nebula (NGC 6543) to be one of the most complex planetary nebulae known.

The final object on this list is **NGC 6543** — the Cat's Eye Nebula — a wonderful planetary nebula you'll find just a bit more than 5° east-northeast of magnitude 3.2 Zeta (ζ) Dra. Through instruments as small as 4 inches in aperture, this colorful object looks blue, blue-green, greenish-blue, or green, depending on your eyes' color sensitivity.

Use a magnification of 200x in an 8-inch telescope, and you'll see some hazy spiral structure around the bright central star. A faint outer shell 5' across surrounds NGC 6543's core.

Point your scope north

I hope this list has convinced you that much more lies within a stone's throw of the North Celestial Pole than a couple of Messier objects. And this is just the beginning. Indeed, a little digging will reveal a terrific selection of all types of deep-sky treats — except for globular clusters — within 25° of the pole. Not only that, but they'll be there for your enjoyment every night of the year.



ROGELIO BERNAL ANDREO

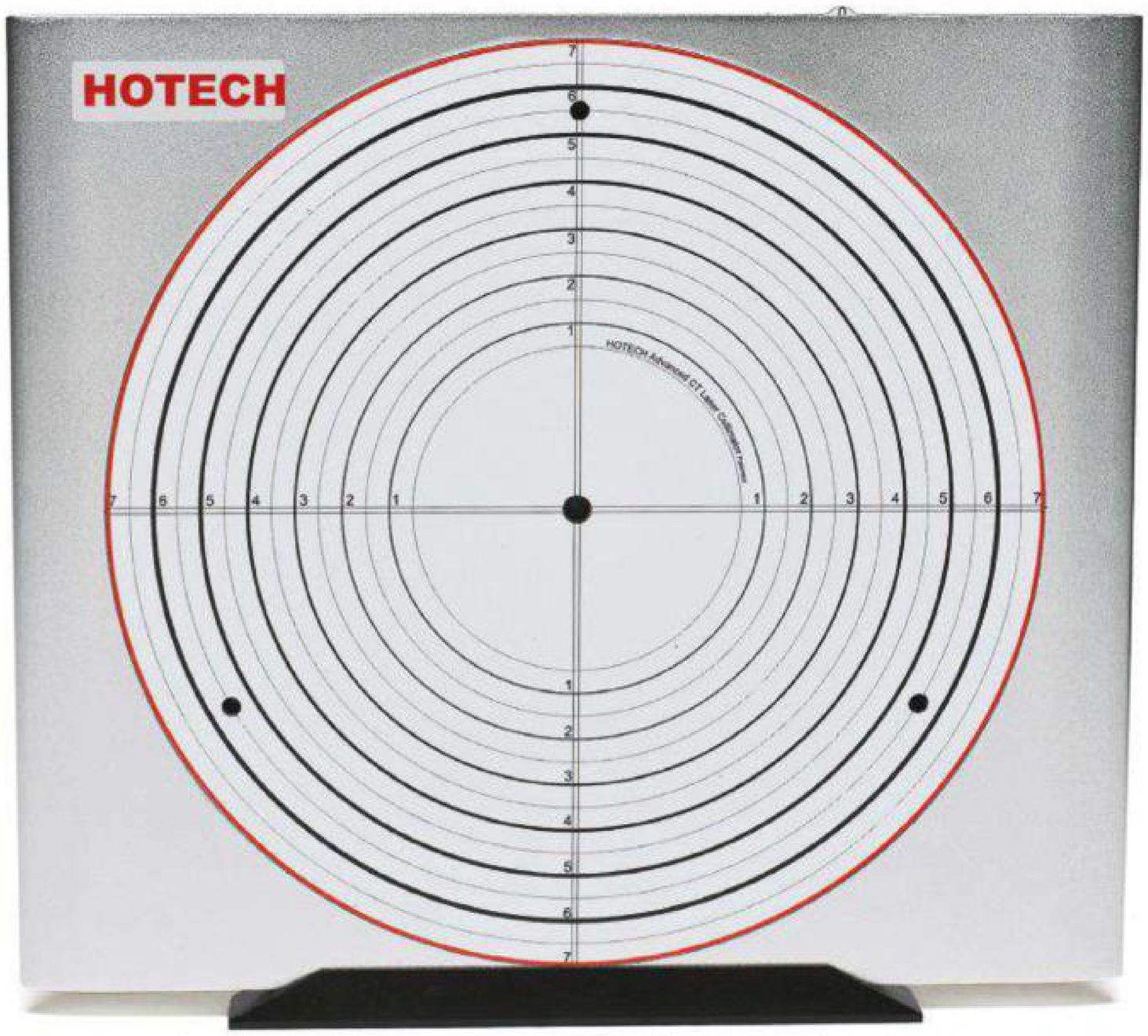
Bode's Galaxy (M81, left) and the Cigar Galaxy (M82) lie in the constellation Ursa Major the Great Bear. The extremely thin dust surrounding the galaxies is what astronomers call the Intergalactic Flux Nebula.

FIND EIGHT MORE FAR-NORTHERN OBJECTS TO EXPLORE AT **www.Astronomy.com/toc.**

StoreMags

Astronomy tests a great new collimator

Align your SCT quickly, easily, and in broad daylight with HOTECH's Advanced CT Laser Collimator. **by Tom Trusock**



HOTECH designed its Advanced CT Laser Collimator to allow observers to align Schmidt-Cassegrain telescopes easily — even during the daytime. *ASTRONOMY:* WILLIAM ZUBACK

No other telescope design offers the combination of features and portability as a Schmidt-Cassegrain telescope (SCT). You may not consider it the best for any one application, but it does everything pretty well. One thing it's not so great at, though, is holding optical alignment, i.e., collimation. Good collimation is a critical step to ensure that you get the best image possible.

Refractors tend to hold collimation well, and they typically arrive with good alignment from the vendor. Most refractor users won't ever have to worry about collimating their telescopes.

Newtonian reflectors require their owners to be familiar with the process, but there's a plethora of tools to assist. SCTs, however, need some care when it comes to collimation, both out of the box and as an ongoing process. I've seen many amateur astronomers dissatisfied with the performance of their SCTs and yet unaware of how to collimate them properly.

Until fairly recently, the best way to collimate an SCT was the star test — checking optical alignment by using a star at night. This can be a frustrating process, especially if the user is unaware of specifics that can affect the test, like poor seeing, an uncooled telescope, differences between mechanical and optical alignment, and other issues. But worst of all for me, star collimation eats into my rather limited observing time.

Wouldn't it be nice to have an easy way to collimate an SCT during the day? Well,



TOM TRUSOCK

The author photographed his collimating setup.

HOTECH has developed the Advanced CT Laser Collimator for just this purpose.

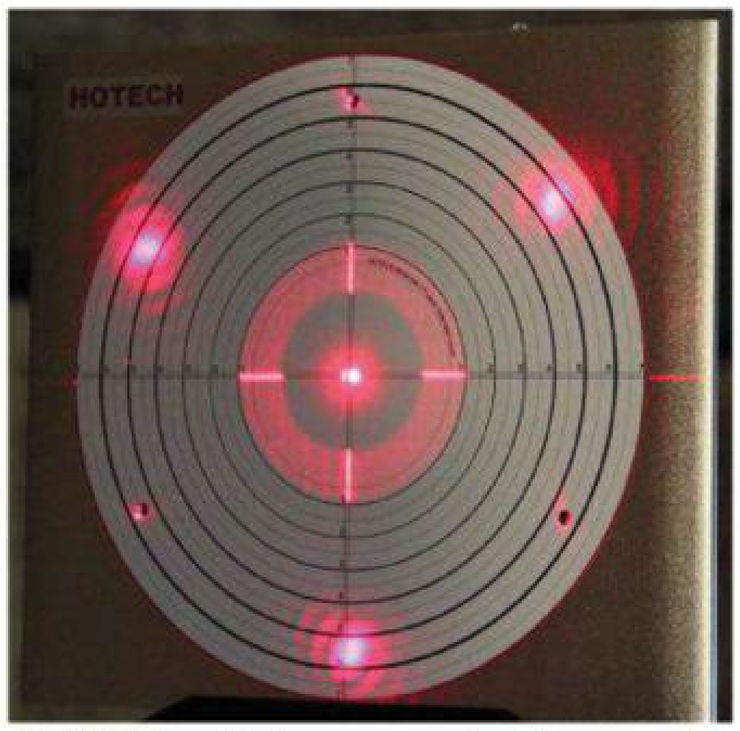
Manufacturers made a few attempts at creating SCT laser collimators in the past, with mixed results. Most of these devices only succeeded in returning you to a known good configuration. In other words, you first had to collimate using the star test. The Advanced CT Laser Collimator does not have that restriction. In addition, the product works for many types of Cassegrain designs — not just SCTs.

Unpack and read

When you open the box, you'll find a high-quality carrying and storage case, the collimator, batteries, the company's Reflector Mirror (1¼" or 2", depending on your order), and an adjustable tripod head for mounting the collimator to a camera tripod, which you have to supply. The tripod head is essential for ensuring that the collimator and telescope square up properly.

The fit and finish of all hardware is top-notch, and the review unit came with both Reflector Mirrors. The standard package includes your choice of return reflector as well as seven pages of instructions, which — I can't emphasize this enough — are

Tom Trusock *tests products from his home in Ubly, Michigan.*



The light from the lasers enters the telescope and returns to the target. At this point, you'll know if the scope's alignment needs tweaking. TOM TRUSOCK



The collimator comes with either HOTECH's 1¼" or 2" Reflector Mirror and an adjustable tripod head. *ASTRONOMY*: WILLIAM ZUBACK

required reading. If you find the instructions a bit confusing or still aren't getting the results you think you should, HOTECH has made videos available on YouTube. If your issue still isn't resolved, call HOTECH directly, and they will be happy to help you.

I had no problems that required either a video or a phone call. When you use HOTECH's product, however, be prepared to abandon most, if not all, of what you know about using a laser collimator.

A simple process

First, install the appropriate Reflector Mirror (1¼" or 2") in the back of your SCT. If you intend to use the scope visually, insert your chosen return reflector into your star diagonal. Then position the collimator at the proper distance as described in the instructions. Proper distance for my setup was right around one tube length.

Next, co-align the collimator and telescope. I found this to be the most time-consuming part of the procedure. But don't skimp here. Make certain that the collimator's support is solid because you don't want it to shift during the process.

The last stage is the optical alignment. Line up the three return spots on the same collimator ring, and you're done. After you use the Advanced CT Laser Collimator for the first time, HOTECH recommends (and I concur) that you check your scope's alignment by performing a star test. The instructions cover this as well.



ASTRONOMY: WILLIAM ZUBACK

The entire kit fits snugly in a padded carrying case.

Assessing the results

The first time I used the device, it took me just under an hour to set up and collimate. As I became more familiar with the steps, however, I became significantly faster, peaking at around 10 minutes.

And once I mastered the procedure, the Advanced CT Laser Collimator did a good job aligning the optics. I did notice via the star test (which I performed each time) that collimation typically required a few tweaks. In looking back, I suspect I was not quite critical enough in ensuring alignment between the collimator and the primary mirror.

I found several mechanical issues that could affect collimation. My 11-inch SCT is an older model that sits atop a German equatorial mount. The primary support structure isn't as solid as it once was. I suspect that SCT users whose telescopes have fork mounts would see a more consistent collimation because the movement of their scopes is limited to two dimensions.

Don't forget that mirror shift can affect the collimation — as die-hard SCT users already know. Mirror shift in an SCT is a byproduct that occurs because manufacturers sometimes choose to focus by moving the primary mirror. A Crayford focuser eliminates that issue because, with it, moving the primary isn't necessary.

Please note, and this is important, that all these issues lie with the SCT and/or the mount, not with the collimator. I point them out here because I feel that some users may experience similar problems and then unfairly blame them on the collimator.

I found that the HOTECH Advanced CT Laser Collimator did a consistently good job of aligning the optics in my scope. If you or your astronomy club are interested in getting the most out of your SCTs while saving valuable observing time, I recommend checking into this product.

PRODUCT INFORMATION

Advanced CT Laser Collimator

Includes: Reflector Mirror, adjustable tripod head, batteries, carrying case

Price (1¼" or 2" model): $455

Contact:

HOTECH
9320 Santa Anita Ave. #100
Rancho Cucamonga, California 91730
[t] 909.987.8828
[w] www.hotechusa.com

StoreMags.com

See SATURN in prime time



Don't wait any longer. The time to observe Saturn is now!

by Michael E. Bakich

Two quick questions: 1) What was the first celestial object you wanted to observe when you had access to a telescope? 2) Which sky object that you show to others through your telescope gets the best reactions? If you're like most amateur astronomers, the answer to both questions is a single word: Saturn.

On May 10, at 2 P.M. EDT (18 hours UT), Saturn reaches opposition — the point in its orbit when it lies opposite the Sun as seen from Earth. The planet then appears as a bright yellowish object at magnitude 0.1 in the constellation Libra the Scales. The warming weather in the Northern Hemisphere will beckon observers to point your telescopes at Saturn.

When you do, you'll see that the planet's northern hemisphere and the north face of the rings currently tilt 21.7° toward Earth. The rings span 42.4", and the planet's equatorial diameter measures 18.7". During times of good seeing (atmospheric steadiness), you will be able to pick out the more prominent features of the globe and rings through a 3-inch telescope.



When Saturn is at opposition, it undergoes a sudden increase in brightness caused by the Seeliger effect. In the case of Saturn's rings, the surge comes from sunlight directly behind the observer (on Earth) illuminating shadows on the ring particles. This image was taken April 3, 2011, at 23h22m UT. DAMIAN PEACH

There's no rush to do this. An apparition (observing season) of Saturn spans a bit more than 10 months. The current one began in late November 2013, when Saturn emerged from the solar glare in the morning sky. The planet will remain visible until October, when it will sink too low in the west after sunset for useful observations.

Planetary features

Novice observers using small telescopes sometimes make the mistake of thinking Saturn's globe is barren and changeless, seldom displaying the kind of activity seen on Jupiter. What you might not know, however, is that Saturn requires nearly twice the magnification as its giant neighbor to produce a disk of comparable dimensions. Once this becomes clear, you'll discover that the planet displays many features that reward regular surveillance.

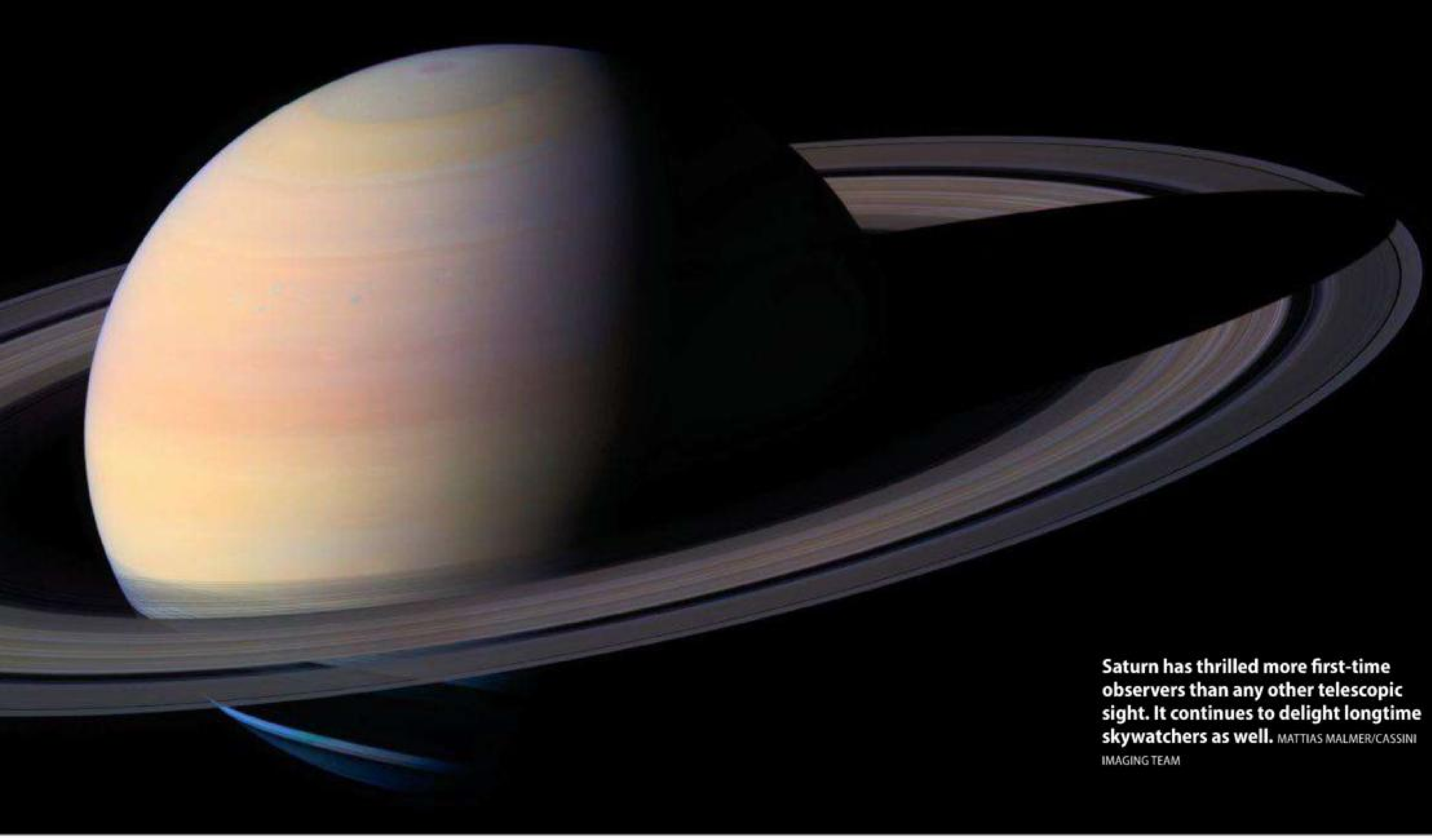
The standard telescope recommendation for detailed studies of Saturn is a high-quality scope with a 6-inch or larger aperture. That said, experienced observers using surprisingly small instruments have achieved remarkable results. The key is to find the right magnification and use it at a pristine site. With that, even a moderate-sized telescope will show a series of white or pale yellow zones and darker yellowish-brown or bluish-brown belts running across the globe parallel to Saturn's equator.

In the Northern Hemisphere, a telescope that flips the image has south up and features moving from right to left (west to east). Also, Saturn's globe casts a shadow on the ring system to the left (east) prior to opposition, to the right (west) after opposition, and casts no shadow at opposition.

Through small telescopes, the obvious features on the globe are the Equatorial Zone (EZ), the North and South Equatorial Belts (NEB and SEB), and the North Polar Region (NPR). Observers with large telescopes may see the SEB divided into north and south components (SEBn and SEBs). Between them lies a brighter region: the South Equatorial Bright Zone (SEBZ). Some less distinct belts and zones, such as the South Tropical Zone (STrZ), South Temperate Belt (STeB), and South Temperate Zone (STeZ), should be visible through 10-inch and larger scopes during good seeing.

Discrete phenomena in the belts and zones, such as dusky festoons and bright ovals, also come into view occasionally. Smaller and less conspicuous white ovals may appear unexpectedly at any time.

High-velocity winds blow in different directions in adjacent bands on Saturn,



Saturn has thrilled more first-time observers than any other telescopic sight. It continues to delight longtime skywatchers as well. MATTIAS MALMER/CASSINI IMAGING TEAM

creating three systems of atmospheric rotation that depend on latitude. System I rotates in 10 hours, 14 minutes, and 13 seconds and includes low-latitude features such as the EZ, NEB, and SEB. System II applies to higher latitudes and completes a rotation in 10 hours, 38 minutes, and 25 seconds. System III refers to polar regions and has essentially the same rate as System I.

If you happen to detect an unusual or transient phenomenon on Saturn, record to the nearest minute when its center is exactly on the globe's central meridian (CM), the imaginary north-south line that divides the planet in half. Then, if you post your finding on the Internet (for example, to the Association of Lunar and Planetary Observers' Saturn section), what you're doing is alerting other observers to watch for the same feature if it appears on the CM in a subsequent rotation.

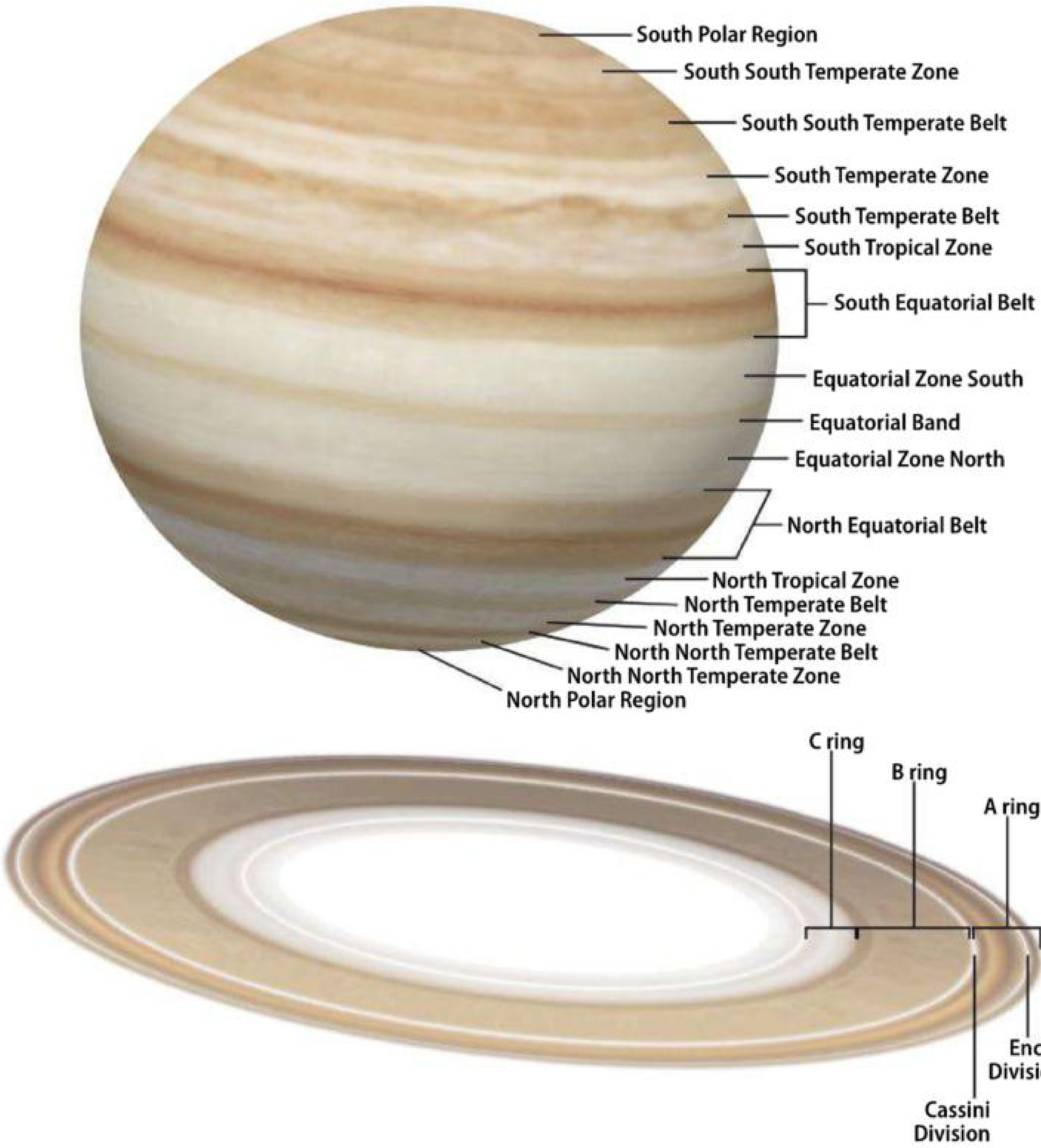
If what you saw lasts long enough for multiple CM passages, astronomers can calculate the rotational rate of Saturn's atmosphere at that latitude. Decades of data on long-lived spots have confirmed a variation in the rotational rates of the SEB and NEB, for example.

Filtering the view

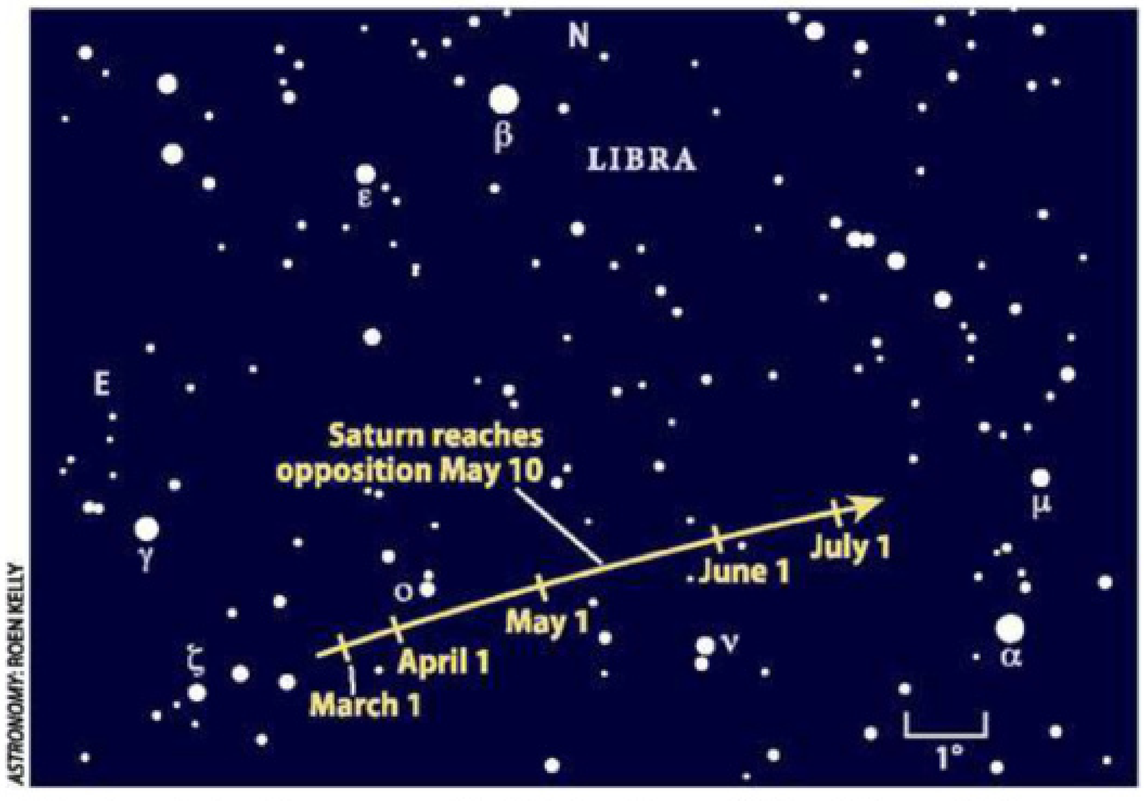
Colors on the disk of Saturn are less bright and show less contrast than those you'll spot on Jupiter. With a large enough scope, you may be able to see a difference in the

Lord of the rings

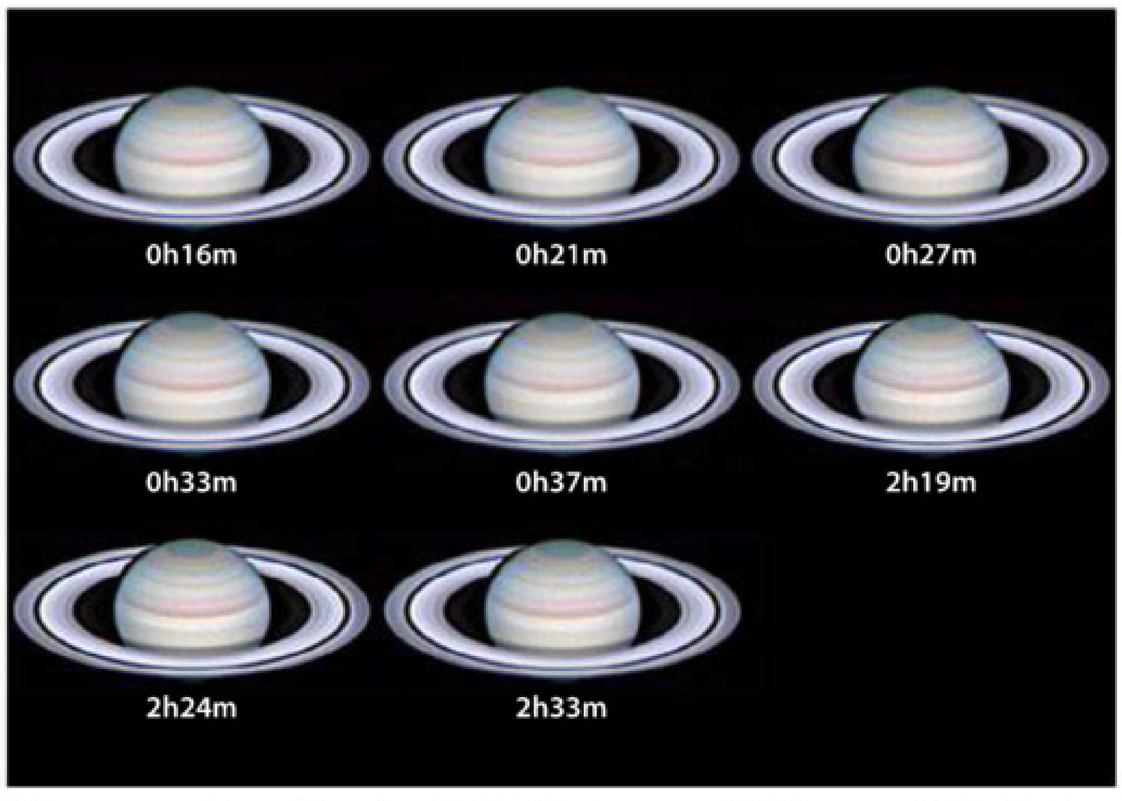
Use this graphic as a guide when you observe Saturn's features. How many can you spot? *ASTRONOMY*: ROEN KELLY



stormdays



The ringed planet appears against the backdrop of Libra at its peak this year. Saturn outshines the constellation's brightest stars, magnitude 2.6 Zubenelgenubi (Alpha [α] Librae) and Zubeneschamali (Beta [β] Librae).



This sequence from December 11, 2004, shows nearly 2 hours and 17 minutes of Saturn's rotation — a bit more than one-fifth of its day. Although atmospheric features are faint, you can still detect how they move. DAMIAN PEACH

color of the rings. For example, one side of the rings may appear brighter than the other when you view through a red filter. If so, switch to a blue filter and see if the brightness variation reverses.

As for the colors themselves, observers describe the brighter zones as appearing off-white, slate-gray, or yellowish at times. Saturn's belts exhibit bluish-gray, brown, and reddish colors easily seen through light red (#23A), red (#25A), orange (#21), or yellow (#12) filters. Brighter patches sometimes appear on the ringed planet and look best through a green (#58) filter. To highlight the rings, use a light green (#56) or a light blue (#80A) filter. Intensity estimates of belts and zones made while using color filters are valuable for monitoring atmospheric features in different wavelengths.

The ring system

The broad rings encircling Saturn's globe are responsible for the planet's exquisite beauty and popularity. Through a medium-sized telescope, it is easy to see the rings divide into three main components of varying brightness.

The outermost of these is the A ring. A dark gap called the Cassini Division, which is visible through a 3-inch telescope, separates it from the brighter central B ring.

The innermost of the major ring components is the C ring, by far the faintest of the three. Just seeing it usually requires a 6-inch scope. Halfway between the outer and inner edges of the A ring is the Encke Division, and eight-tenths of the way out from the globe in the A ring is the very narrow Keeler Gap. Most observers agree that seeing the Encke Division requires an aperture of about 8 inches, and the Keeler Gap is within reach of 10-inch instruments.

Saturn's axis of rotation tilts with respect to its orbit by about 27°, and consequently, the inclination of the ring system to our line of sight varies between 0° and 27° north and south. At opposition this May, its rings tilt 21.7° with the north edge facing Earth. And the tilt will increase for several more years until it reaches a maximum in October 2017. (At opposition June 15, 2017, Saturn's rings will tilt 26.6° to our line of sight.) Then the tilt will diminish until the rings are edgewise in March 2025.



This image of Saturn taken May 29, 2013, shows many details observers search for. Notice the wide, dark Cassini Division, plus the Encke Division, on each side of the rings. The planet's bands also appear quite distinct. CHRISTOPHER GO

Saturn's moons

Of Saturn's 62 known satellites, only about seven have significance to observers. The faintest of them is Mimas, at visual magnitude 12.1. It's difficult to find because it lies close to Saturn, so seeing Mimas requires a large aperture. Enceladus, at visual magnitude 11.7, fluctuates in brightness and also is hard to detect with anything smaller than a 10-inch telescope.

Tethys and Dione are both near magnitude 10.6, so you can spot them through a 4-inch scope when they're far from Saturn's globe. Rhea, at visual magnitude 10.0, is easy to see using a 3-inch telescope and may exhibit brightness variations. The brightest moon, reddish Titan, which shines at visual magnitude 8.3, makes an easy target through a 2.4-inch instrument.

But perhaps the most interesting saturnian satellite is Iapetus. Its visual magnitude ranges from 10.1 to 11.9, depending on where it is in its orbit around Saturn. From data returned by the Voyager spacecraft, we know that one face of Iapetus is bright, reflecting 50 percent of the Sun's light, while the other is quite dark, reflecting only 5 percent of the light that strikes it. You can see Iapetus through a 3-inch telescope when the moon is at its brightest, which occurs when the moon reaches greatest western elongation.

If you'd like to try something just a bit more challenging than simply identifying Saturn's satellites, try to estimate the brightness of each one. Compare them to nearby stars in the same way observers make estimates of variable stars.

Estimating the magnitude of a moon is a bit more complicated because the apparent brightness of a satellite is a function of its distance from Saturn's brilliant globe and how much of the Sun's light the moon reflects. But you'll get the hang of it after just a few evenings of practice.

However you choose to observe the ringed planet, even if it's only a casual look every now and then, Saturn will not disappoint you. Its atmosphere, moons, and glorious ring system offer countless hours of fun at the eyepiece.

Michael E. Bakich *is a senior editor and the photo editor of* Astronomy. *He loves to crank up the magnification when he observes Saturn.*

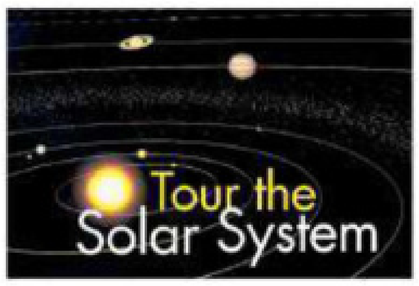
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What's new at Astronomy.com.
BY KARRI FERRON

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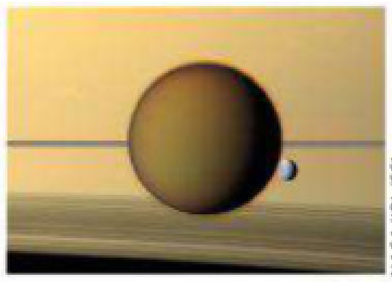
Featured video

"Tour the Solar System: Saturn"



No planet evokes as much awe through a telescope as Saturn and its stunning system of rings. And because the ringed world reaches its peak in May, there's no better time than right now to learn about the planet everyone at the eyepiece will be talking about. To find out the basics, be sure to watch "Tour the Solar System: Saturn." Did you know that 700 Earths could fit inside Saturn, or that moons hide among the planet's rings? In this video, you'll get tons of fun facts like these, plus you'll find out why so many cartoons show Saturn in a bathtub, uncover what those magnificent rings are made of, explore the planet's intriguing moons, and much more.


NASA/JPL/SSI


NASA/JPL/SSI

"Tour the Solar system: Saturn" and all the other videos in the *Tour the Solar System* series are available to registered members of Astronomy.com. Registration is easy, so sign up today and head to **www.Astronomy.com/solarsystem** to learn more about this fascinating world.

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OBSERVING TOOLS

Weekly podcast

Each week, Senior Editor Michael E. Bakich shares a podcast featuring three deep-sky objects you can see in the next seven days. He adds variety by selecting targets for various optics: some for binoculars, some for small telescopes, and others for larger instruments, like an 8-inch scope. He even shares bonus objects, whether multiple sets of double stars, a pair of star clusters, or a group of galaxies. No matter what his targets, though, Bakich always provides detailed observing information and fun facts about each choice. Get the inside scoop at **www.Astronomy.com/podcast**.

COMMUNITY



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Browse thousands of beautiful astroimages like this one of the Intergalactic Wanderer (NGC 2419) taken by Fred Herrmann and submit your own. Not an astroimager? You still can explore our numerous gallery catalogs, including Galaxies, Nebulae, Stars and Star Clusters, Planets, the Sun and Moon, Comets, and Cosmic Creations. Comment on photos and learn from other imagers' techniques. Beginners and advanced amateurs anywhere in the world are welcome at **www.Astronomy.com/readergallery**. We publish new photos regularly!

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Comet ISON may have vaporized — but our photo contest hasn't!

Join the National Science Foundation, *Astronomy* magazine, and *Discover* magazine for a big announcement of our Comet ISON Photo Contest winners! The contest features prizes up to $2,500.

Many astroimagers shot great images of the comet (C/2012 S1) from September through November 28. *Astronomy* Editor David J. Eicher will announce and show the competition's winning photos at the **2014 Northeast Astronomy Forum, Saturday, April 12,** at Rockland Community College in Suffern, New York.

For more information on NEAF, see:
www.rocklandastronomy.com/neaf

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DAMIAN PEACH



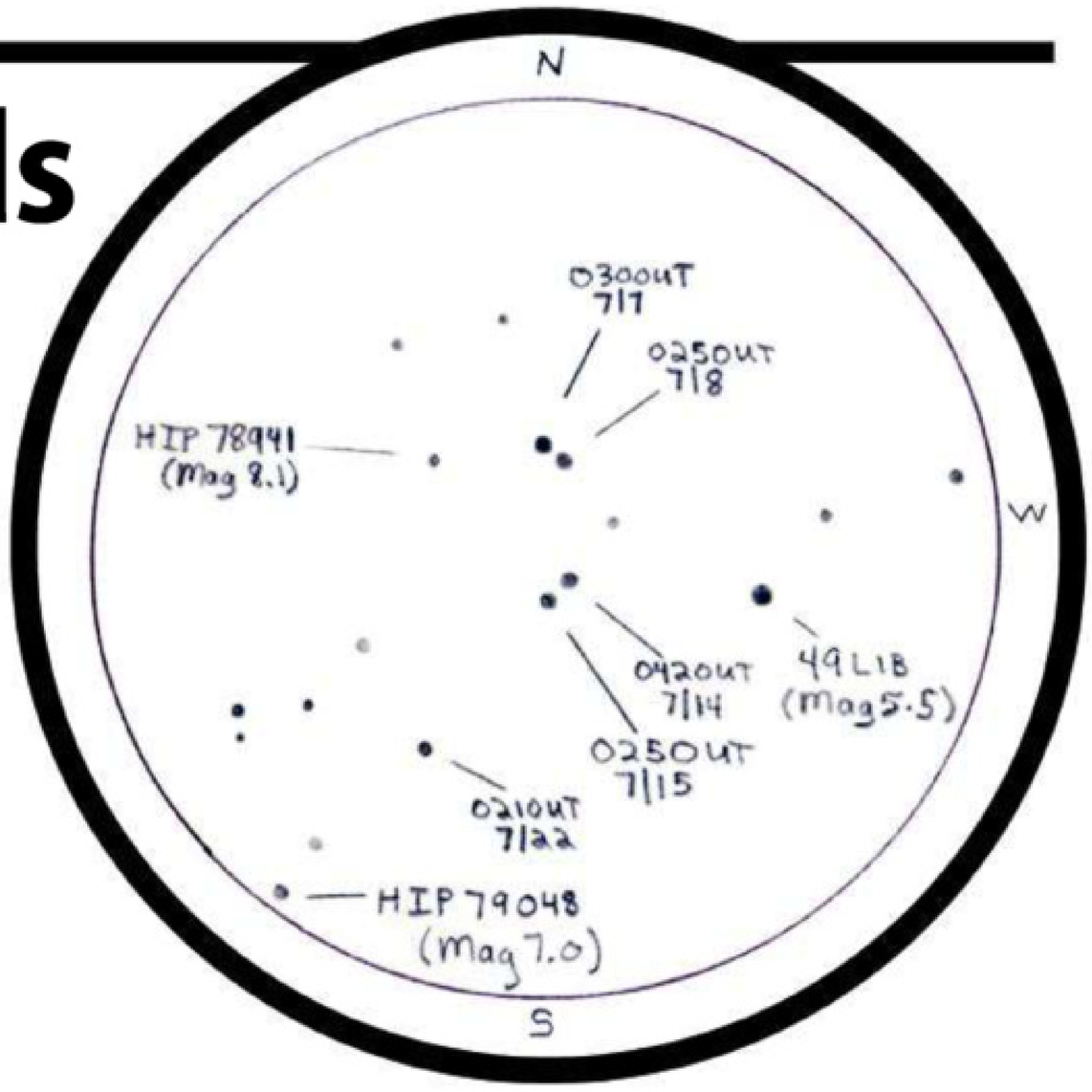
BY ERIKA RIX

Tracking asteroids

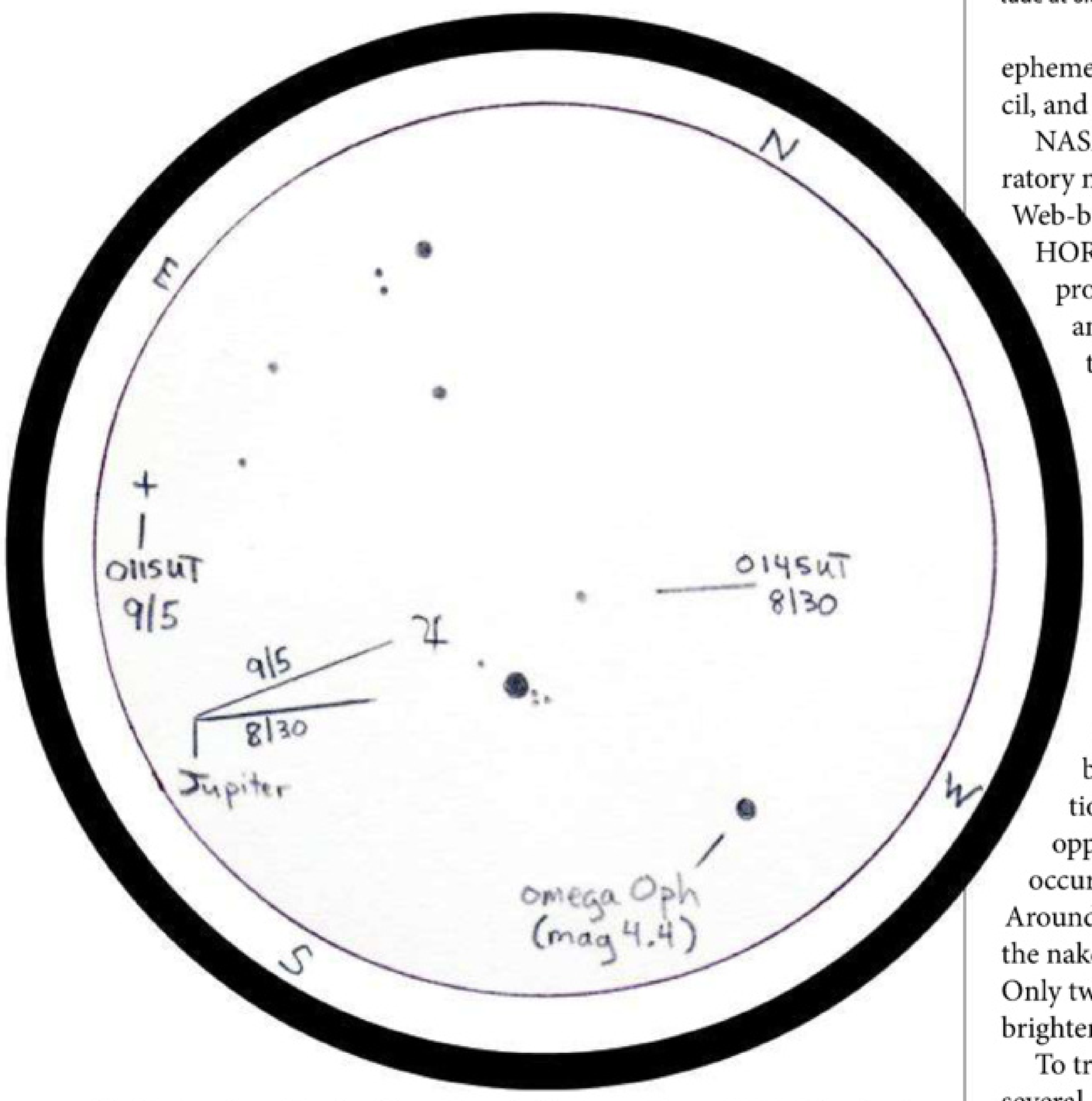
Within the main asteroid belt, which lies between Mars and Jupiter, are two of the oldest and most massive surviving residents, Ceres and Vesta. The formation of Jupiter interrupted their growths, and during the past 4.5 billion years, they have taken opposite evolutionary paths. Vesta is a rocky asteroid whose face basaltic lava flows and impacts have changed. Ceres, on the other hand, remains basically in its icy primordial state, although cratered.

This pair presents a great opportunity for scientists to study the origin and evolution of our solar system. As part of NASA's Discovery Program, the agency launched the Dawn spacecraft in 2007 on an 8.5-year voyage through the asteroid belt. Scientists already have received data from Dawn's 14-month rendezvous (July 2011 to September 2012) with Vesta, and now the craft is en route to allow Ceres' gravitational pull to capture it in March 2015.

Vesta and Ceres, measuring 326 miles (525 kilometers) wide and 590 miles (950km) wide, respectively, are too small for observers to spot surface details using earthbound telescopes. You can, however, locate these bodies and track their positions. All you need is an up-to-date ephemeris, a sketchpad, a pencil, and binoculars or a scope.



This sketch shows Vesta's positions July 7, 8, 14, 15, and 22, 2007. Note how the drawing includes several labeled stars with their magnitudes in parentheses. The sketcher used 15x70 binoculars with a field of view of approximately 4.4°. He estimated Vesta's magnitude at 6.0 on July 7, fading to between 6.8 and 7.0 by July 22.



This drawing shows Vesta less than 0.5° north of Jupiter on August 30, 2007. The sketcher returned to this region six days later and recorded the two objects again. He used 15x70 binoculars with a field of view of approximately 4.4°. BOTH SKETCHES BY MICHAEL ROSOLINA

NASA's Jet Propulsion Laboratory made available a limited Web-based interface to its HORIZONS system, which provides solar system data and accurate ephemerides that you can tailor to specific observing dates and locations. Just head online to http://ssd.jpl.nasa.gov/horizons.cgi.

As luck would have it, both asteroids are currently viewable in the constellation Virgo the Maiden. (See "View Ceres and Vesta at their best" on p. 52.) Opposition (when an object lies opposite the Sun in our sky) occurs April 13 for Vesta. Around that time, it is visible to the naked eye at magnitude 5.8. Only two days later, Ceres brightens to 7th magnitude.

To track an asteroid over several days, the star field you sketch must be large enough to include room for the asteroid's projected path. Label the names and magnitudes of a few known stars, and then mark the north-south and east-west orientations. Asteroids look just like stars, but they will have moved relative to the stars when you revisit them a few hours later.

Plot Vesta or Ceres within the star field, and compare its magnitude to the surrounding stars. Label the date, time, and your estimate of its magnitude next to each plotted position, or record the positions by letters with the relevant data noted just outside the sketch circle.

And be aware that there may be some added value to your efforts: The Amateur Observers' Program supports the Dawn mission and welcomes written reports and sketches that show the motion of asteroids over several nights. Visit its website at http://dawn-aop.astro.umd.edu/index.shtml to learn how you can contribute.

Do you have questions or suggestions? Contact me at erikarix1@gmail.com.

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Vixen's VSD100F3.8 astrograph features a five-element apochromatic objective lens that completely removes blue halos around stars. The lens boasts a 99.9 percent light transmission with no flare or ghost images. It has a focal length of 380 millimeters.

Price: $6,299
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Price: $169.99
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Focuser controller

JMI Telescopes
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JMI Telescopes' MOTOFOCUS for the William Optics DDG focuser installs in one minute. This small lightweight unit for the Digital Display Gauge focuser manufactured by William Optics allows focusing movements as small as 0.01 millimeter.

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Astronomy camera

Orion Telescopes & Binoculars
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Orion's StarShoot All-In-One Astrophotography Camera contains a ⅓-inch color CMOS sensor with 3.75-micron by 3.75-micron pixels. It features a video rate from 30 to 200 frames per second and a single exposure range from 0.00002 second to 10 minutes. You also can use the camera as a wide-field digital finder or an autoguider.

Price: $379.99
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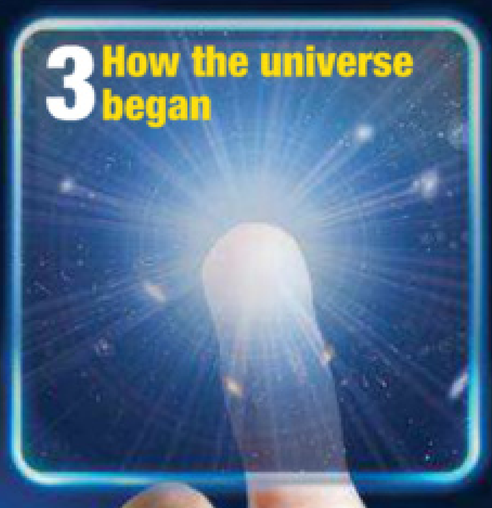
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P22250



COSMIC**IMAGING**

BY ADAM BLOCK

Lighten up!

In this column, I want to highlight a few basic ideas concerning image layers and conditional blending modes. Although I'll use *Photoshop* as the demonstration software, the ideas are applicable to most software that handles image processing. Once you have a complete understanding of these ideas, it will allow you to appreciate other advanced techniques.

I realize some readers find numbers daunting, but there's no way around them here, so be fearless! If you are proficient in *Photoshop*, you can try to do the following example in your head. Otherwise I encourage you to sit at your computer for five minutes and construct the image I describe below.

We will be working with four gray colors. Each has a brightness value, like those you would find in an 8-bit image, that ranges from 0 to 255. The bottom layer is black (value = 0) with the gray letters A and B. A has a brightness value of 85, and B has one equal to 200.

The upper layer is gray, which has a value of 150. In *Photoshop*, you can assign gray colors by specifying equal values in R, G, and B in dialog screens when you either create text or fill with a color. When you display this in the "Normal" blending mode, whatever visible portions of an upper layer there are display over an underlying one. In our case, this will yield a gray screen. Making this layer invisible will show the lower layer with the embedded A and B (see far left image).

Now with both layers visible, change the blending mode to "Lighten." The result (see middle image) will show the letter B on a gray background. "Lighten" is a conditional blending mode that picks the brighter pixels from the two layers. Note that for the modes we are using, it does not matter which layer is on top. The gray you see is coming from the upper layer with the value of 150 because it is greater than 0. This gray upper layer is also brighter than the value of A, so that letter doesn't show. B has the brightest value, so the program displays it, even though it actually resides in the lower layer.

When you fully understand my description, please blend the images using "Darken." The far right image is the result. It shows the letters A and B as well as the black background. "Darken" is the anti-"Lighten" and chooses the darker pixel values between the two layers. This resulting image looks similar to the lower layer with an invisible upper gray layer.

What is going on? You probably expected the black value to show because it is darker than the upper gray layer. This is also true for A. Note, however, that the B is not in its original form. It gets its color from the upper gray layer because 150 is smaller than 200. So, this B is a bit darker than the original B.

These conditional blending modes are powerful global means of blending layers. Instead of selectively adjusting images, we can choose suitable brightness thresholds to blend images in powerful ways. In my next column, I'll show you how to modify the standard use of the "High Pass Filter" with remarkable results.

FROM OUR INBOX

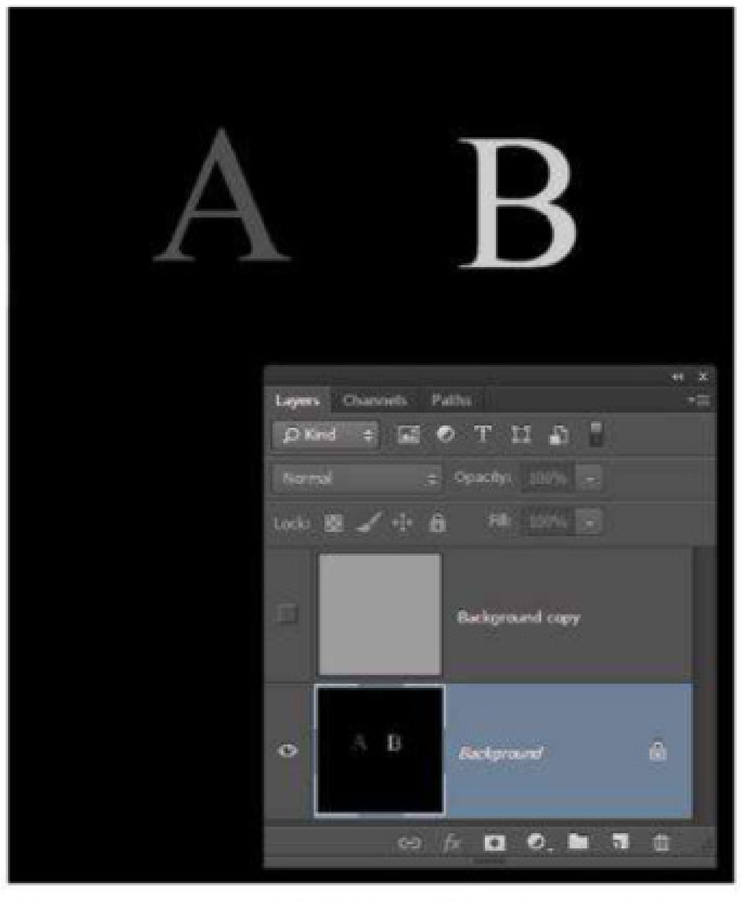
Tupperware on Titan:
The science behind the discovery

I have to come clean. After reading the "Quick Takes" note (p. 18) in the January 2014 issue about finding propylene on Titan, I have to take the blame.

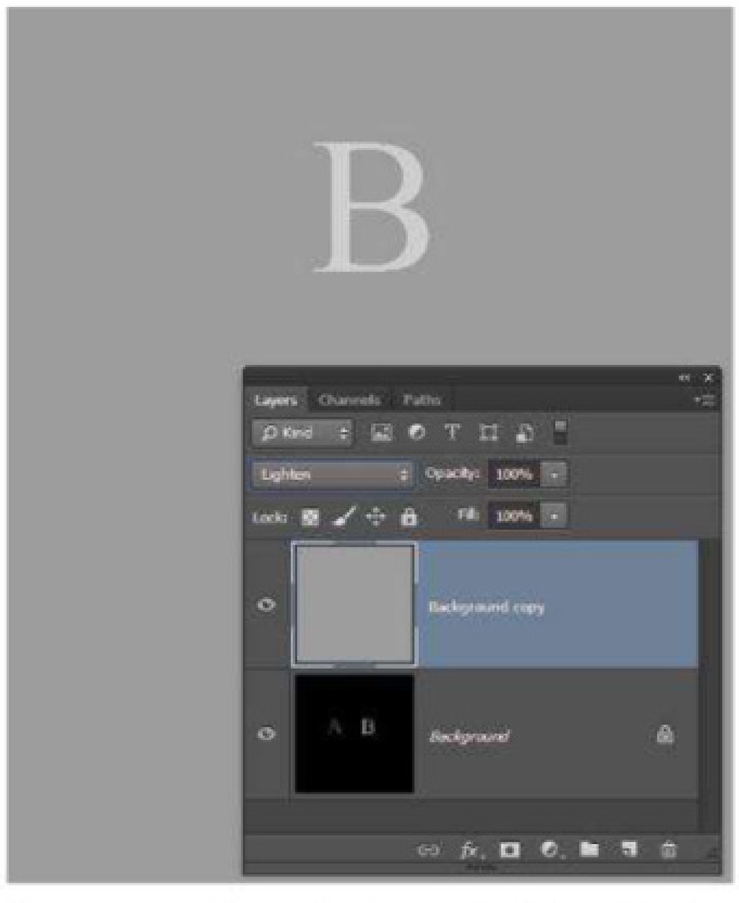
When I was 12 years old, I used one of my mother's Tupperware bowls for a science experiment. She was angry with me, so to get back at her, I cut the bowl into pieces, loaded it into a specially made Estes rocket with 47 stages, and blasted it into space. I was actually aiming for Saturn, but I evidently hit Titan instead — not bad for a 12-year-old with a slide rule!

OK, fine, this is pure spoof. I know I would have had to equip the rocket with oxygen to launch it out of the atmosphere. It probably landed somewhere in Ohio. Astronomers will have to find another explanation for the space-based propylene!

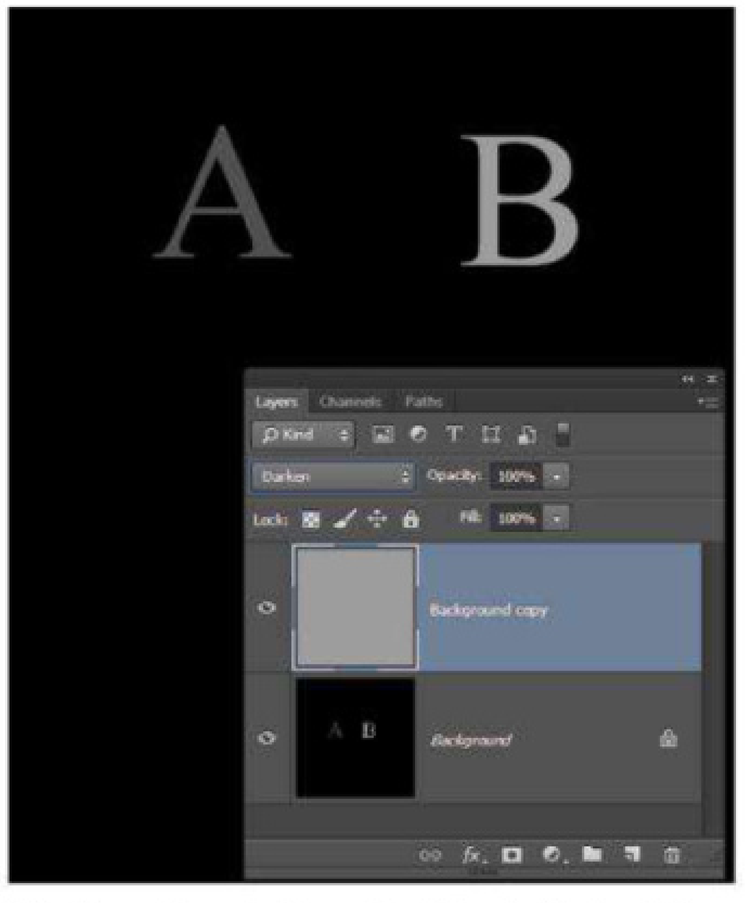
— **David Giesen,** Platteville, Wisconsin



When the author used the "Normal" blending mode, he made the upper gray layer invisible, so only the lower layer with the embedded A and B show. ALL IMAGES: ADAM BLOCK



Here the author blended the layers using "Lighten." And although the B resides on a lower level, it's brighter so it shows on the gray background.



This picture shows the layers blended using "Darken." Compare the B in this image to the one at the far left. It is darker because it took the darker gray from the upper layer.

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COMING IN OUR

NEXT ISSUE

WEIRD MOONS of the solar system

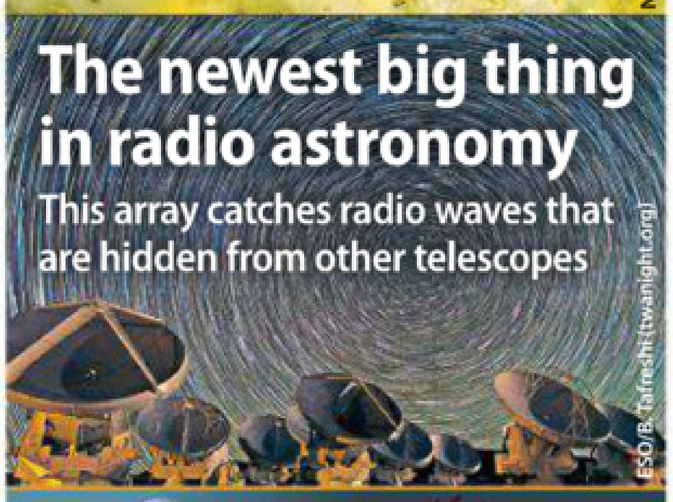
From a *Star Wars* satellite to a sponge-like celestial body, discover the oddities of planetary moons



NASA/JPL-Caltech/Univ. of Arizona

The newest big thing in radio astronomy

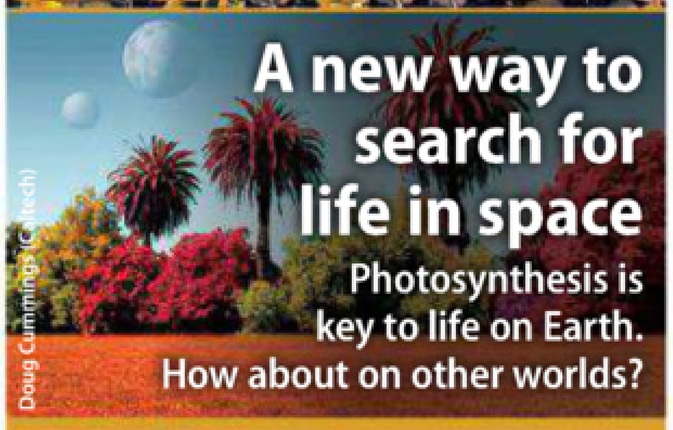
This array catches radio waves that are hidden from other telescopes



ESO/B. Tafreshi (twanight.org)

A new way to search for life in space

Photosynthesis is key to life on Earth. How about on other worlds?



Doug Cummings (Caltech)

PLUS

- How to observe nebulae that vary
- Chasing the Moon's shadow through Africa
- Starmus rocks astronomy
- Remote observing takes a giant leap forward
- Testing Sky-Watcher USA's new refractor

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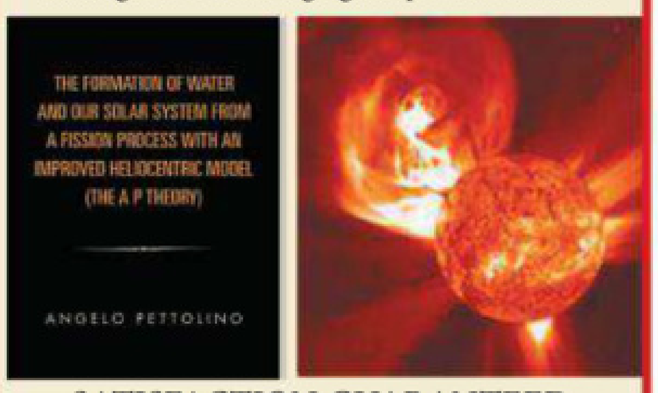
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READER GALLERY



1

1. GRAND REFLECTOR
M78 in the constellation Orion the Hunter is the sky's brightest reflection nebula. It shines at magnitude 8.0 and lies some 1,600 light-years away. (5.6-inch Telescope Engineering Company TEC-140 refractor at f/7, SBIG ST-8300M CCD camera, LRGB image with exposures of 9, 3, 3, and 3 hours, respectively) • ***Bernard Miller***

2. SUPERNOVA IN M82
On the evening of January 21, 2014, an undergraduate class led by astronomer Steve Fossey at the University of London discovered Supernova 2014J in the Cigar Galaxy (M82). Near the end of January, the exploding star shone at 10th magnitude and would have been brighter except for dust within M82. (32-inch RC Optical Systems Schulman Telescope, SBIG STX-16803 CCD camera, RGB image with 75 minutes of exposure through each filter, taken January 23, 2014) • ***Adam Block/Mount Lemmon SkyCenter/University of Arizona***



2

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3. THE SPIDER NEBULA

IC 417 is an emission nebula that shines because of radiation from a newly formed star cluster at its center. It lies in the constellation Auriga the Charioteer. The Spider spans nearly 10 light-years and lies 10,000 light-years away. (5.2-inch Takahashi TOA-130 refractor, SBIG STT-8300 CCD camera, HαRGB image with exposures of 8, 1.5, 1.5, and 1.5 hours, respectively) • ***Fred Herrmann***



4



5



6

4. GALACTIC DUST

Sharpless 2–63 is a faint molecular cloud in Sagittarius the Archer. One of its other designations, MBM 159, comes from a 1985 survey of high-galactic-latitude molecular clouds by astronomers Loris Magnani, Leo Blitz, and Lee Mundy. (16-inch Dream Telescopes Astrograph at f/3.75, Apogee Alta U16M CCD camera, LRGB image with exposures of 60, 6, 6, and 6 minutes, respectively) • ***Kfir Simon***

5. BALL OF SUNS

Globular cluster NGC 1261 lies in the constellation Horologium the Clock. The fuzzy objects are much more distant galaxies in the same field of view. (20-inch PlaneWave corrected Dall-Kirkham reflector at f/4.5, FLI PL-6303E CCD camera, LRGB image with exposures of 30, 5, 5, and 5 minutes, respectively) • ***Damian Peach***

6. DARKNESS IN THE LIGHT

Dark nebula Barnard 343 lies in Cygnus. In 10 million years or so, this region will shine by the light of a newly formed star cluster. (5.2-inch Takahashi TOA-130F refractor at f/7.7, Quantum Scientific Instruments QSI 540wsg CCD camera, HαRGB image with exposures of 140, 10, 10, and 10 minutes, respectively) • ***Jeff Johnson***



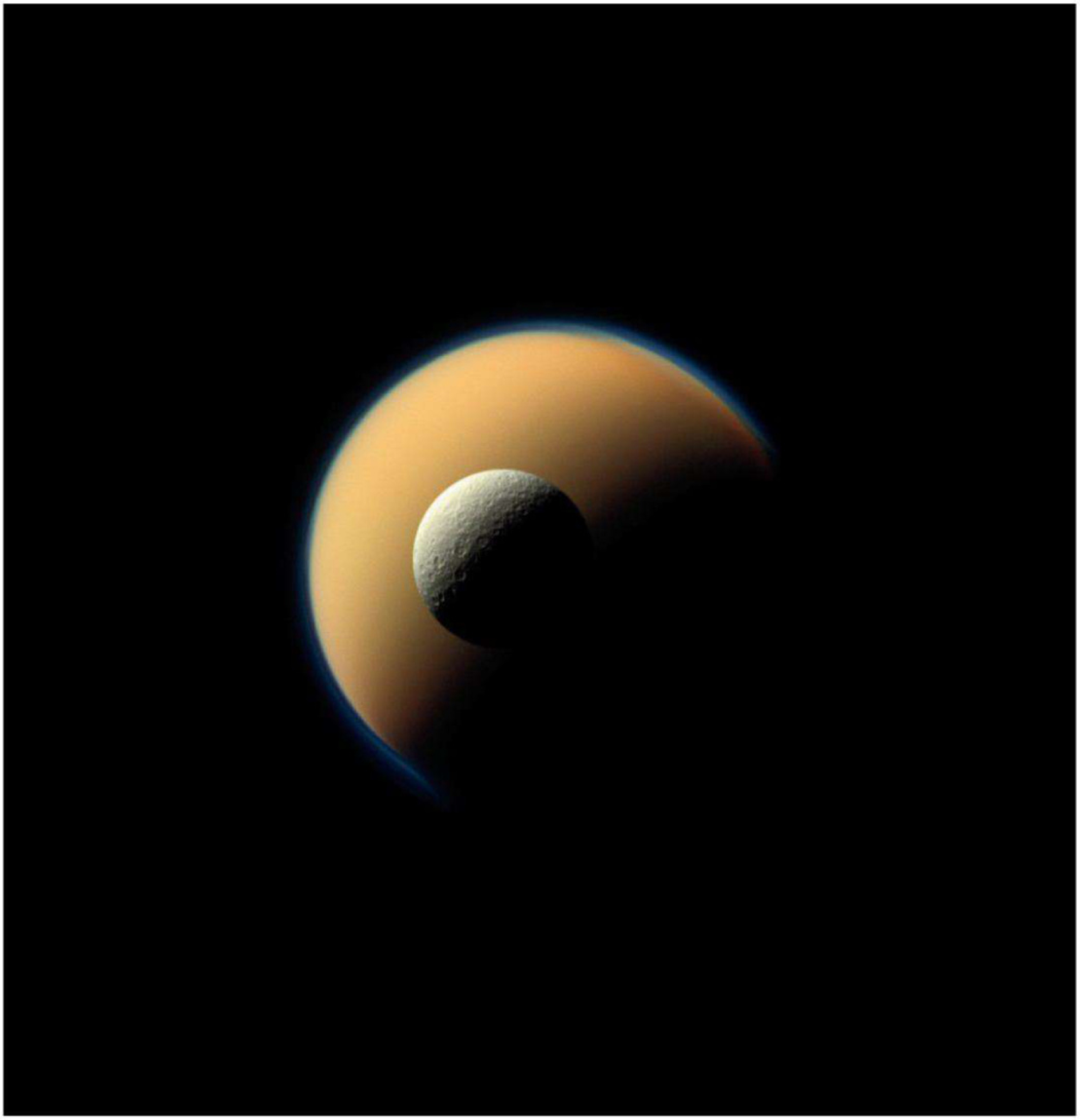
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7. MEGA MOSAIC

The field of view of this image covers numerous nebulae in the constellations Lacerta and Pegasus. Sharpless 2–126 is the largest red area on the left, and LBN 438 is the big red region just above center. You also can spot NGC 7331, the brightest galaxy to the upper right. North is to the left. (4-inch Takahashi FSQ-106EDX refractor at f/3.6, SBIG STL-11000M CCD camera, four-panel mosaic of HαRGB images with 16 hours total exposure) • ***John A. Davis***

Send your images to:

Astronomy Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures. Submit images by email to readergallery@astronomy.com.



NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE

Fire and ice in Saturn's shadow

A striking image from the Cassini spacecraft shows two of Saturn's moons, Titan and Rhea, apparently stacked up as they orbit the ringed planet.

Titan, the large orangish moon in the background, is the only solar system satellite with a dense atmosphere. It is a strange world because it also contains abundant liquids, mostly consisting of methane and ethane, flowing on its surface. It has sometimes been nicknamed the "gasoline planet" because of this offbeat environment. Could Titan host a strange kind of life that we might not recognize?

Floating in front of Titan is the icy world Rhea, smaller than Titan and a moon pockmarked by craters. This peculiar body consists of perhaps as much as 75 percent water ice, and its surface is not only cratered but fractured and marked with rays and strange ice cliffs.

ONE HALF OF THIS IMAGE WAS TAKEN WITH A $2,499 ESPRIT

Imager: Jerry Keith of Fort Worth, Texas
(Three Rivers Foundation Volunteer)
Scopes: Sky-Watcher Esprit 100mm EDT f/5.5
World-class 4-inch astrograph
Mount: Takahashi EM200 Temma2M
Guiding: Orion SSAG Magnificent Mini AutoGuider
Camera: Canon 60Da @ 800 ISO
Exposure: 20 light frames and 20 dark frames @ 300 seconds.
No flats, dark flats or bias frames were used.
30 light frames and 15 dark frames @ 30 seconds
were used for toning down the core of M31.
The same processing was used for both scopes.

THE OTHER WAS TAKEN WITH A SCOPE THAT COST TWICE AS MUCH

Actually, the other telescope cost **more** than twice as much as the Esprit, but that's not really the point. The point is, do you see twice as much performance on one side of the page than the other? Take a close look. Are the stars twice as pinpoint? Is the color doubly corrected?

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MARTIN GEORGE describes the solar system's changing landscape as it appears in Earth's southern sky.

July 2014: Mars meets Spica in Virgo

As the second half of the year begins, two planets feature prominently in the evening sky. As twilight fades to darkness, **Mars** gleams high in the northern sky. On July 1, the Red Planet appears 6° to the lower left (northwest) of blue-white Spica, Virgo's brightest star. The two show a nice color contrast, which appears vivid through binoculars.

Although Spica remains fixed in the starry firmament, Mars' orbital motion around the Sun causes it to move eastward relative to the background stars during July. By the 11th, the planet slides within 2° of the star, and it remains that close through the 17th. Mars appears due north of Spica July 12 and 13. At magnitude 0.2, the planet outshines the star by nearly a magnitude.

It's still worth viewing Mars through a telescope, but the planet's best days are behind it. A 10-centimeter or larger instrument will show the white north polar cap and a few more-subtle features, particularly during moments of good seeing. These prime observing opportunities happen most often when the planet lies high in the north during the early evening. As Mars moves farther from Earth this month, its disk shrinks from 9" to 8" across.

A 55-percent-lit waxing Moon occults Mars on July 6. The event can be seen from much of northern South America. From Lima, Peru, the planet disappears behind the Moon's dark limb at 2h13m UT and reappears from behind the bright limb at 3h31m UT.

Saturn lies well to the right (east) of Mars and trails its sibling by about 90 minutes as they cross the sky. The ringed planet shines at magnitude 0.4 among the much fainter background stars of Libra.

The sight of Saturn through a telescope impresses beginning and experienced observers alike. If you target the planet in early evening when it lies highest in the north, even a small telescope will deliver rewarding views. In mid-July, Saturn's disk appears 18" across while the rings span 40" and tilt 21° to our line of sight. Small scopes also reveal the planet's brightest moon, 8th-magnitude Titan.

Two days after the waxing gibbous Moon occults Mars, our satellite passes in front of Saturn. People in the southern third of South America can watch this spectacular event under a dark sky July 8. From Buenos Aires, Argentina, Saturn disappears behind the Moon at 3h05m UT and reappears at 4h01m UT.

You might catch a glimpse of **Jupiter** low in evening twilight during the first few days of July. It then lies less than 10° above the northwestern horizon a half-hour after the Sun goes down. At magnitude –1.8, the planet glows brightly enough to see under good conditions, especially through binoculars. Jupiter quickly disappears from view as it prepares to pass on the Sun's far side July 24.

Shortly before twilight starts to paint the sky, magnitude –3.8 **Venus** rises in the northeast. In early July, the bright planet lies near the Hyades star cluster in Taurus, but its rapid motion eastward carries it into central Gemini by month's end. This region hangs low as twilight brightens the sky. Through a telescope, Venus spans 11" and displays a fat gibbous phase.

Innermost **Mercury** is also a morning object. It reaches greatest elongation July 12, when it lies 21° west of the Sun. On that morning, the planet appears 7° (about one binocular field) to the lower right of brilliant Venus. A telescope reveals Mercury's 8"-diameter disk and waxing crescent phase. The sight of the two inner planets near each other will warm observers brave enough to get up early on these cool mornings.

The starry sky

As a young astronomy enthusiast, I was keen to learn the names of the sky's brightest stars. Like most beginners, I started by studying the summer constellations, and it took some time before I got around to the winter constellation Libra the Balance (or Scales).

I was surprised, and not a little amused, by Libra's unusual star names. The constellation's two brightest stars are Zubenelgenubi (Alpha [α] Librae) and Zubeneschamali (Beta [β] Lib). These names come from Arabic and mean "southern claw" and "northern claw," respectively. This might seem odd, considering that a balance doesn't have claws, but the answer becomes clearer when you realize that Libra's stars were once an extension of the pattern forming Scorpius the Scorpion.

There's more to this story, however. Take a look at Libra some evening this month — it's easy to find thanks to Saturn's presence — and you will see that Alpha and Beta are a bit too close to each other to make ideal claws for the Scorpion. Scan several degrees above Saturn and you'll spot Sigma (σ) Lib, which you might think would make a better southern claw than Alpha based on its position.

Indeed, you are right. Sigma, whose proper name is Zubenhakrabi ("scorpion's claw") was once considered part of Scorpius and received the designation Gamma (γ) Scorpii. Some people think that Zubenelgenubi would be a more suitable name for this star because it makes a worthier southern claw.

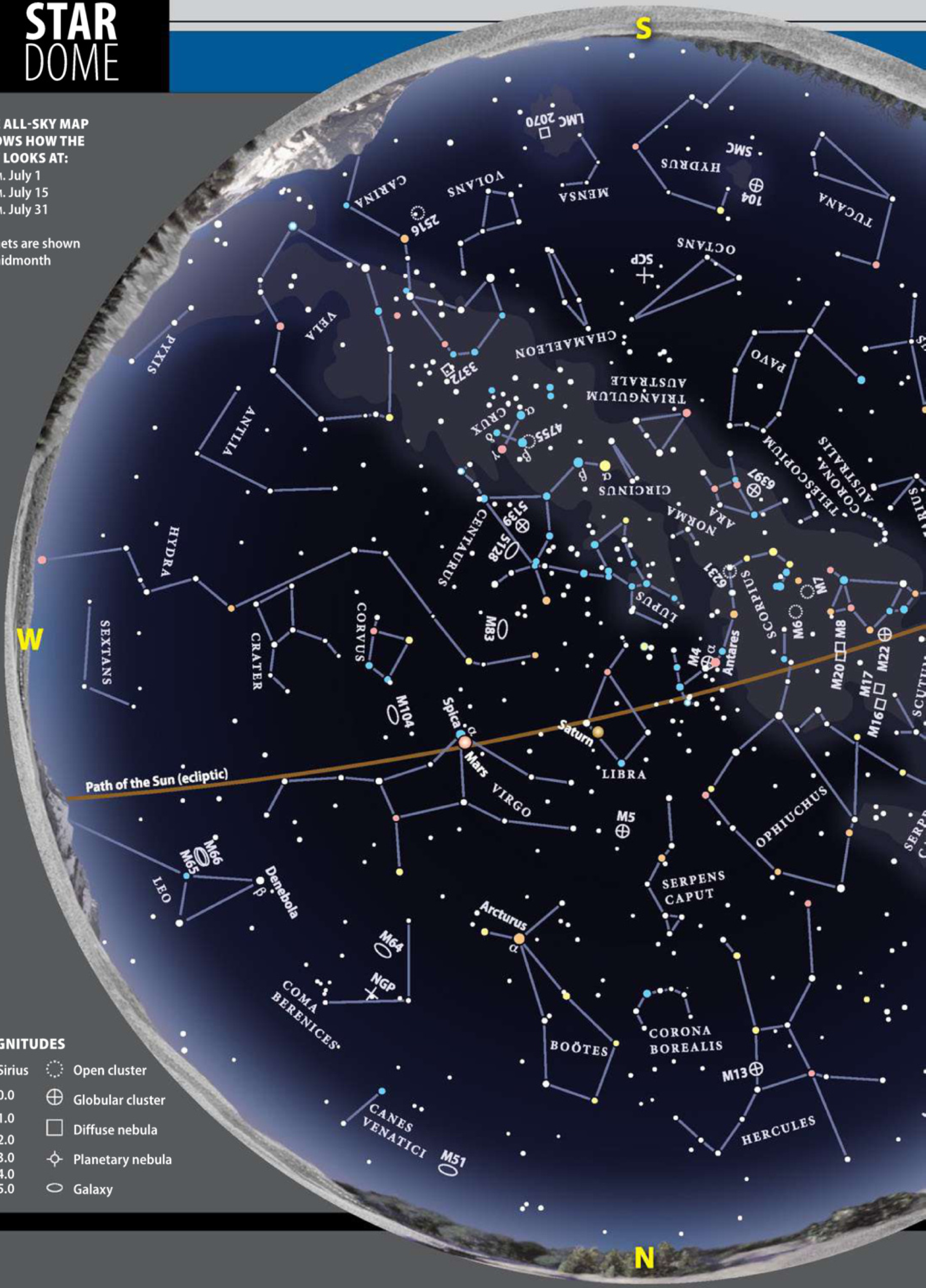
The confusion over the names of Libra's stars was made worse when 19th-century celestial cartographer Elijah Burritt erroneously used the name Zubenhakrabi for the star Eta (η) Librae.

Observationally, Zubenelgenubi is an attractive double star. The pair's wide separation makes it a fine binocular object. In May 1966, astronomers at Kitt Peak Observatory in the United States watched the Moon occult the brighter star and discovered that it is a close double star itself.

STAR DOME

THE ALL-SKY MAP SHOWS HOW THE SKY LOOKS AT:
9 P.M. July 1
8 P.M. July 15
7 P.M. July 31

Planets are shown at midmonth



MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy



HOW TO USE THIS MAP: This map portrays the sky as seen near 30° south latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

STAR COLORS: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white without optical aid.

Illustrations by *Astronomy*: Roen Kelly

JULY 2014

Calendar of events

1 Mercury is stationary, 14h UT

2 Venus passes 4° north of Aldebaran, 10h UT

4 Earth is at aphelion (152.1 million kilometers from the Sun), 0h UT

Pluto is at opposition, 8h UT

5 First Quarter Moon occurs at 11h59m UT

6 The Moon passes 0.2° north of Mars, 1h UT

8 The Moon passes 0.4° south of Saturn, 2h UT

12 Full Moon occurs at 11h25m UT

Mercury is at greatest western elongation (21°), 18h UT

Mars passes 1.4° north of Spica, 23h UT

13 The Moon is at perigee (358,260 kilometers from Earth), 8h26m UT

15 The Moon passes 5° north of Neptune, 17h UT

18 The Moon passes 1.4° north of Uranus, 10h UT

19 Last Quarter Moon occurs at 2h08m UT

21 Saturn is stationary, 15h UT

22 Uranus is stationary, 9h UT

24 The Moon passes 4° south of Venus, 18h UT

Jupiter is in conjunction with the Sun, 21h UT

26 New Moon occurs at 22h42m UT

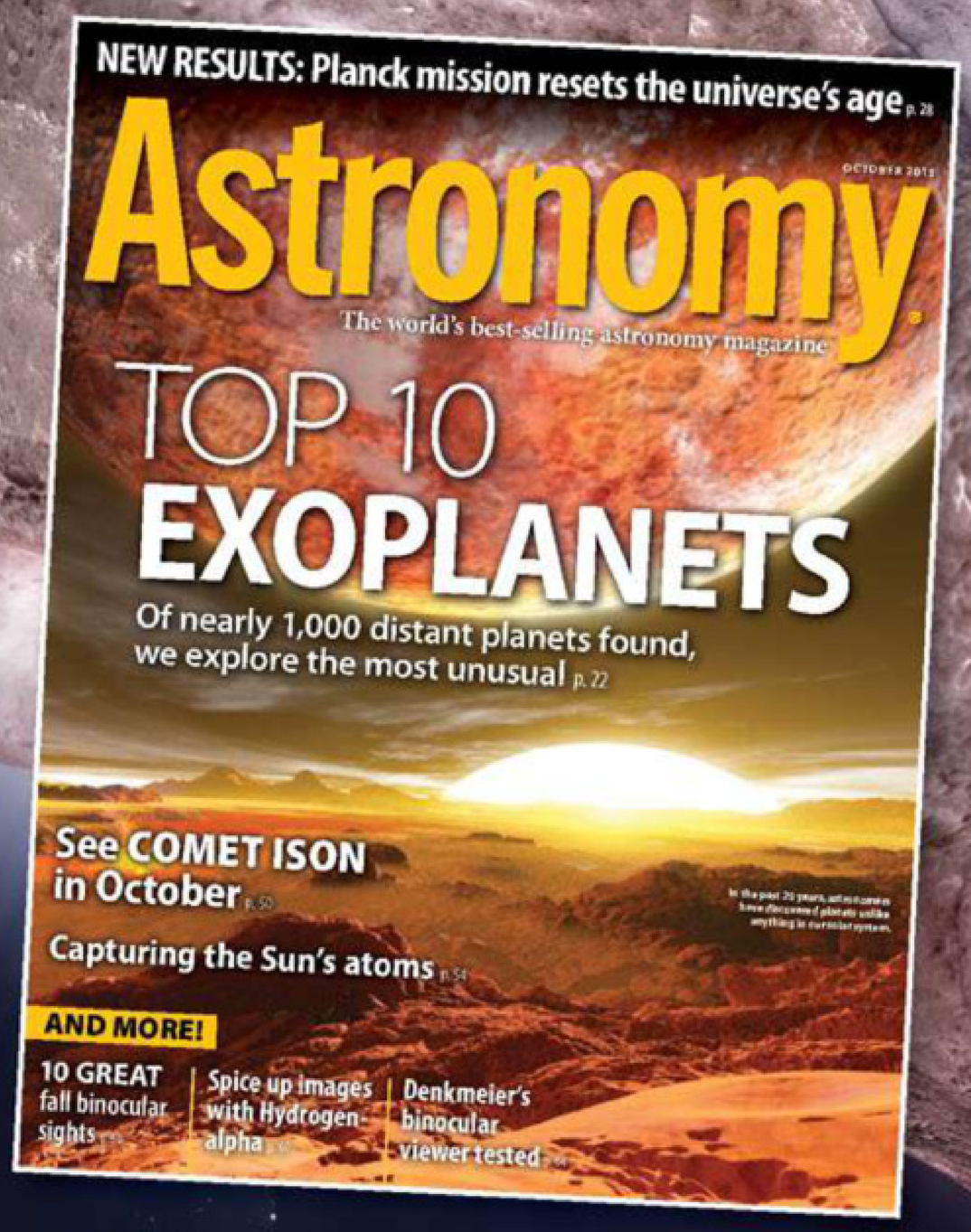
28 The Moon is at apogee (406,567 kilometers from Earth), 3h28m UT

29 Mercury passes 6° south of Pollux, 5h UT

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